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Contractor's Final Report [1]
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ENFOR Project P-170

Evaluation of Potential Interactions Between Forest Biomass Production and Canadian Wildlife

by

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June 1983

FOREWORD

ENFOR is the bilingual acronym for the Canadian Forestry Service's ENergy from the FORest (ENergie de la FORêt) program of research and development aimed at securing the knowledge and technical competence to facilitate, in the medium to long term, a greatly increased contribution from forest biomass to our nation's primary energy production. This program is part of a much larger Federal Government initiative to promote the development and use of renewable energy as a means of reducing our dependance on petroleum and other non-renewable energy sources.

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Ottawa, Ontario
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or the Director of the establishment issuing the report.

This report, a result of ENFOR project P-170, was prepared under contract (DSS File 42SS. KL229-0-4224) by Le Groupe Dryade, more specifically by Rodrigue Coulombe, for. eng. and André B. Lemay, biologist.

ABSTRACT

Forest management for biomass production can be undertaken in all provinces of Canada. Raw material can be extracted either from sawmills, logged areas, silvicultural treatments or short-rotation intensive culture. All forests are suitable habitats for wildlife. However, some species (woodland caribou, lynx, marten, owl,...) are extremely dependant on mature forests. Logging these forests generally contribute to reduce habitats and thus populations. Management of second growth forests should take into consideration these species by extending rotations so part of the forests will serve these species. Removal of snags and downed logs to increase amount of raw material will contribute to reduce habitats of, for instance, tree-nesting birds. As these aspects have not been intensively studied within the Canadian forest regions, interactions can hardly be specified. Studies are recommended to analyse the overall problems and define measures to prevent detrimental effects. Other species (rare, threatened or endangered) will need specific attention and precaution while managing forests. Some are highly sensitive to noise and human disturbance (Whooping Crane, White Pelican, Peregrine Falcon,...), others are very sensitive to harassment. Increased human presence within managed forests will necessitate more educationnal programs to prevent detrimental effects. Some species of reptiles, amphibians and fishes are so poorly documented that only basic studies of the biology, ecology and distribution will permit to identify and evaluate interactions with these new forestry concepts.

RESUME

L'aménagement des forêts pour la production de biomasse forestière peut se faire dans toutes les provinces canadiennes. Celle-ci peut être prise à même les résidus des scieries, sur les parterres de coupe, lors de traitements sylvicoles ou en produisant celle-ci sur de très courtes rotations. Ces forêts fournissent également abris et nourriture pour la faune. Certaines espèces (caribou, lynx, martre, hibou,...) ont un grand besoin des forêts matures pour assurer leur bien-être. La coupe de ces forêts contribue généralement à réduire la quantité d'habitats disponibles, diminuant par le fait même leur population. L'aménagement des forêts de seconde venue devrait également prendre en considération cette faune des forêts matures en s'assurant qu'une partie des peuplements atteignent cet état de maturité. La récolte des chicots, et des tiges que l'on retrouve normalement sur les parterres forestiers réduiront sensiblement les habitats nécessaires, par exemple, aux espèces nichant dans les cavités des arbres morts. On ne connait actuellement pas, pour nos forêts canadiennes, la quantité, la disponibilité et l'utilisation faite par la faune de ces habitats. Des études devraient être entreprises pour effectuer l'analyse globale du sujet afin de définir les mesures préventives à prendre pour atténuer les effets négatifs probables. Les espèces rares, menacées ou en voie d'extinction devront être tout spécialement prises en considération lors de l'aménagement intensif des forêts. Certaines sont très sensibles au bruit et à la présence humaine (la Grue blanche d'Amérique, le Pélican blanc, le Faucon pélerin,...). D'autres sont très sensibles au harcèlement. L'augmentation de la présence humaine conséquente à l'aménagement intensif des forêts nécessitera de plus grands efforts d'éducation pour prévenir des situations fâcheuses. Certaines espèces de reptiles, d'amphibiens et de poissons sont tellement peu connues que seules des études biologiques, écologiques et de distribution permettront d'identifier et d'évaluer les interactions avec ces nouveaux concepts d'aménagement.

Dryade
Conseillers en environnement

Quebec City, July 26 1982

Mr. E.S. Telfer
Program Leader, Parks Canada
Canadian Wildlife Service
Western and Northern Region
Environment Canada
1000 - 9942, 108th Street
Edmonton, Alberta
T5K 2J5

Dear Mr. Telfer,

We are pleased to present herewith our final report entitled «Evaluation of potential interactions between forest biomass production and canadian wildlife», as per our contract 0SS80-00106.

Our principal findings are that forest biomass production will increase the existing pressure on wildlife, especially rare, threatened, endangered species and recreational species. Removal of tops, branches, snags and downed logs will deprive wildlife from suitable habitats for shelter and reproduction. A decrease of population is predicted if appropriate mitigative measures are not identified and tested now. Much more dialogue between forest and wildlife managers will be necessary to optimize both forest biomass and wildlife production. We hope that our study will be useful to both parties so Canadians can always enjoy this natural heritage.

LE GROUPE DRYADE

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INTRODUCTION

Canada is physiographically, floristically and faunistically diverse, and much of it forested (Simpson-Lewis et al., 1979). It extends over 9 974 thousand km^2 of which somewhat more than 92% is land. Of this total land area, 37% is classified as forested land, 8% is agricultural land while the remaining 55% comprises all other land. Of the forested land (3681 thousand km^2), 77% is owned by provincial governments, 17% by federal (North West Territories and National Parks) government, and the remaining 6% is privately owned. 2 934 thousand km^2 of the forested land have been inventoriated and 67% is considered productive. Coniferous species account for about 80% of the growing stock. Spruce, balsam fir, jack and lodgepole pines comprise the coniferous growing stock. Hemlock, ponderosa pine and Douglas fir are also abundant, but occur mainly in British Colombia. Poplar and aspen are the most abundant hardwood species in Canada and account for one-half of total hardwood volume. Almost one-half of Canada's poplar stocks occur in the Prairie Provinces and the remaining stocks occur in Ontario where it accounts for about one-half of the province's hardwood volume. White birch, maple, yellow birch and beech are abundant in Ontario, Québec, New Brunswick and Nova Scotia. The annual allowable cuts (AAC) for managed and non-managed land currently total 215 million m^3 of which 81% is softwood. However, the economically accessible AAC is about 140 million m^3. Harvests are expected to reach 220 million m^3 by the year 2000. The current AAC Canada-wide appears to be sufficient to support annual harvests of 220 million m^3 by the year 2000. However, it may be inadequate to support expanded harvests in some regions, especially New Brunswick and Nova Scotia. Programs have been already initiated to rehabilitate stands that have deteriorated due to past utilization practices and to accelerate restocking on burned and cut-over forest land. Silvicultural programs have also been initiated to increase future harvest and to increase current AACs in various regions.

All of Canada's surface area may be considered as wildlife land and capable of maintaining a variety of species groups such as insects, fish, reptiles, amphibians, birds and mammals. Each group contributes to the ecological diversity of the country. There are approximately 198 species of mammals, 550 species of birds, 46 species of amphibians, 60 species of reptiles, 181 species of fish and more than 75 000 species of insects that are known to spend at least some stages of their life cycle in Canada. The use of land by these species is a function of several factors, of which the most important are the availability of habitat and the adaptability of species to changing environmental conditions. Some species, for example the Whooping Crane, prairie dog, Kirtland's warbler, and wood bison, depend on specialized habitat conditions while others, such as the Herring Gull, beaver and white-tailed deer, are more flexible in satisfying their needs and can adjust to moderate changes in habitat.

In the past, Canada has relied on non-renewable energy sources for development. However, shortages and escalating prices have forced a new perspective on the energy situation. The sun, wind, tides and forests, renewable energy sources which until recently were ignored, are now being reviewed to determine their harnessable potential. The forests of Canada, with 1 943 thousand km^2 of forest land represent a potential landbase for biomass production. The potential use of biomass (heat, electricity, gas) depends largely on proximity to the natural distribution of the resource itself. Much of the Atlantic Region, Québec, Ontario, Manitoba, Saskatchewan and British Colombia are suitable areas on that regard. A large shift to more intensive forest exploitation necessitates an upgrading of forest management. Not only would the same resource have to meet existing demands by pulp and paper and lumber industries but would also have to meet wood heating applications.

1.- STUDY OBJECTIVES AND SCOPE

Given the present and future Canadian energy situation, wood or forest biomass are expected to be more and more intensively used to produce energy as well as paper, lumber and other forest products. Pressure on productive forest land will increase more and more in the coming decades. Improved technologies will help to increase quantity and quality of forest products. In this situation we face the problem of predicting how the biological components and more particularly wildlife will react to those changed forest conditions.

The purpose of the present study is to posit a general model in order to identify and appraise potential interactions between maximum forest biomass production and Canadian wildlife with special regard to rare, threatened and endangered species (flora and fauna), game species and pests (wildlife likely to damage trees). Results should stress our actual knowledge of the matter and point out studies that should be undertaken before the new management concepts be implemented on a larger scale.

2.- GENERAL APPROACH AND METHODS

To reach the stated objective, the study has been divided into distinct steps ranging from data gathering to general and specific recommendations following the analysis of interactions. Defined methods centre on three major topics:

- Maximum forest biomass management practices applicable to Canadian forest regions.
- Identification of species of concern and definition of their habitat requirements.
- Potentiel interactions between management practices and wildlife of concern and recommendations.

2.1- Data gathering

This first step consisted in searching for the most pertinent and up to date information related to the three major subjects of concern. This research has been conducted all across Canada and mainly directed to federal and provincial governments and to private agencies. Appendix I enumerates agencies consulted or contacts made with people involved in each discipline.

2.2- Data analysis

Collected information has then been analysed and regrouped under general headings for groups of provinces with similar conditions to show:

- basic information related to forest inventories (species, stand composition, area, volume, regeneration,...)
- management practices from stand establishment to harvesting, road construction, fire control,...
- specific data related to biomass production (extensive and intensive)

- flora and fauna of concern (rare, threatened, endangered, game and pest species) encountered in regions where biomass production could become a common practice
- analysis of the ecology and biology in order to regroup species using forest habitats in a similar way (life form sensu Thomas, 1979).

Data accumulated in the study have been integrated to highlight impacts of such management on selected wildlife, mitigative measures to attenuate negative effects and optimize positive effects. Recommendations of studies to fill information gaps are then identified. These recommendations are related to either missing basic data, evaluation of impacts or mitigative measures.

Report is divided into 4 sections:

- Forest biomass production
- Wildlife of concern
- Potential interactions
- Recommendations

3.- FOREST BIOMASS PRODUCTION

The objectives of this section are to elaborate conceptual models of the type of landscape that would result in the provinces and various forest regions of Canada, if management for energy production becomes common. Conceptual models will be based on a general description of the resource itself, description of biomass management practices regrouped under alternatives and application of defined alternatives to various forest regions.

3.1- The resource and its location

Forest biomass could be produced anywhere in Canada except the tundra regions. In fact «by the process of photosynthesis the sun's energy is captured by trees and plants and used to convert carbon and water to wood fibre, bark, leaves, flowers, fruit and seeds. This vegetation, collectively referred to as forest biomass, represents a tremendous storage of chemical energy in a form that can be used as fuel» (Simpson Lewis _et_ _al._, 1979). However, this rather new concept of energy production will have to share the same land as other uses, such as agriculture, forestry, recreation, urban developments,.... Table 1 summarizes for each province, the major facts about our land. Roughly, excluding Yukon and the North West Territories, total land covers over 5,5 million km^2 of which 56% is classified as forest land, 12% farmland, 5% parks, and 27% other lands (open areas, tundra, urban,...). Of the forested land, 2 620 thousand km^2 have been inventoriated and 72% considered as productive.

These forested lands, according to Rowe (1972) could be regrouped under eight major regions of which four are specific to southwestern Alberta and British Colombia. Main characteristics of these regions are discussed in Table 2 and location is illustrated in Figure 1. The Aspen Parkland, part of the Boreal Forest Region (Rowe, 1972), in the southern central Prairie Provinces is considered in this study as a distinct forest region.

TABLE I

LAND OWNERSHIP AND LAND USE BY PROVINCES AND TERRITORIES
(thousands of square kilometers).

PROVINCE	OWNERSHIP				LAND USE									
	TOTAL LAND AND WATER AREA	Crown		Private	TOTAL LAND AREA	FOREST			FARMLAND			PARK		OTHER
		Federal	Provincial			Productive	Unproductive	Total	Improved	Unimproved	Total	National	Provincial	
Newfoundland	404	3	383	18	370	85	250	335	-	-	-	2	7	26
Prince Edward Island	6	-	1	5	5	1	1	2	2	1	3	-	-	-
Nova Scotia	56	2	15	39	53	38	2	40	2	2	4	1	-	8
New-Brunswick	73	2	31	40	71	61	2	63	3	3	6	2	-	-
Québec	1 540	3	1 425	112	1 480	374*	61*	614	21	14	35	1	88	742
Ontario	1 068	10	939	119	894	426	140	566	44	20	64	3	43	218
Manitoba	650	5	500	145	548	161	186	347	52	25	77	9	3	112
Saskatchewan	652	15	389	248	573	80**	44**	289	189	75	264	4	5	11
Alberta	661	63	337	261	644	202	126	328	109	87	196	54	6	60
British Columbia	952	9	888	55	933	515	-	515	7	16	23	35	4	356
Total	6 058	112	4 905	1 041	5 571	1 943	812	3 099	429	243	672	111	156	1 533
%	100	2	81	17	100	35	15	56	8	4	12	2	3	-
Yukon and North West Territories	3 916	3 912	4	-	3 786	-	-	526	-	-	-	64	-	3 196
TOTAL (Canada)	9 974	4 024	4 909	1 041	9 357	2 503[1]	1 178[1]	3 625	429	243	672	175	156	4 729
%	100	40	49	10	100	27	12	39	5	2	7	2	2	50

* Excludes 179 thousand square kilometers of forest land not inventoriated.

** Excludes 165 thousand square kilometers of forest land not inventoriated.

[1] Proportion of productive and improductive forest lands has been estimated from provincial adding.

TABLE 2

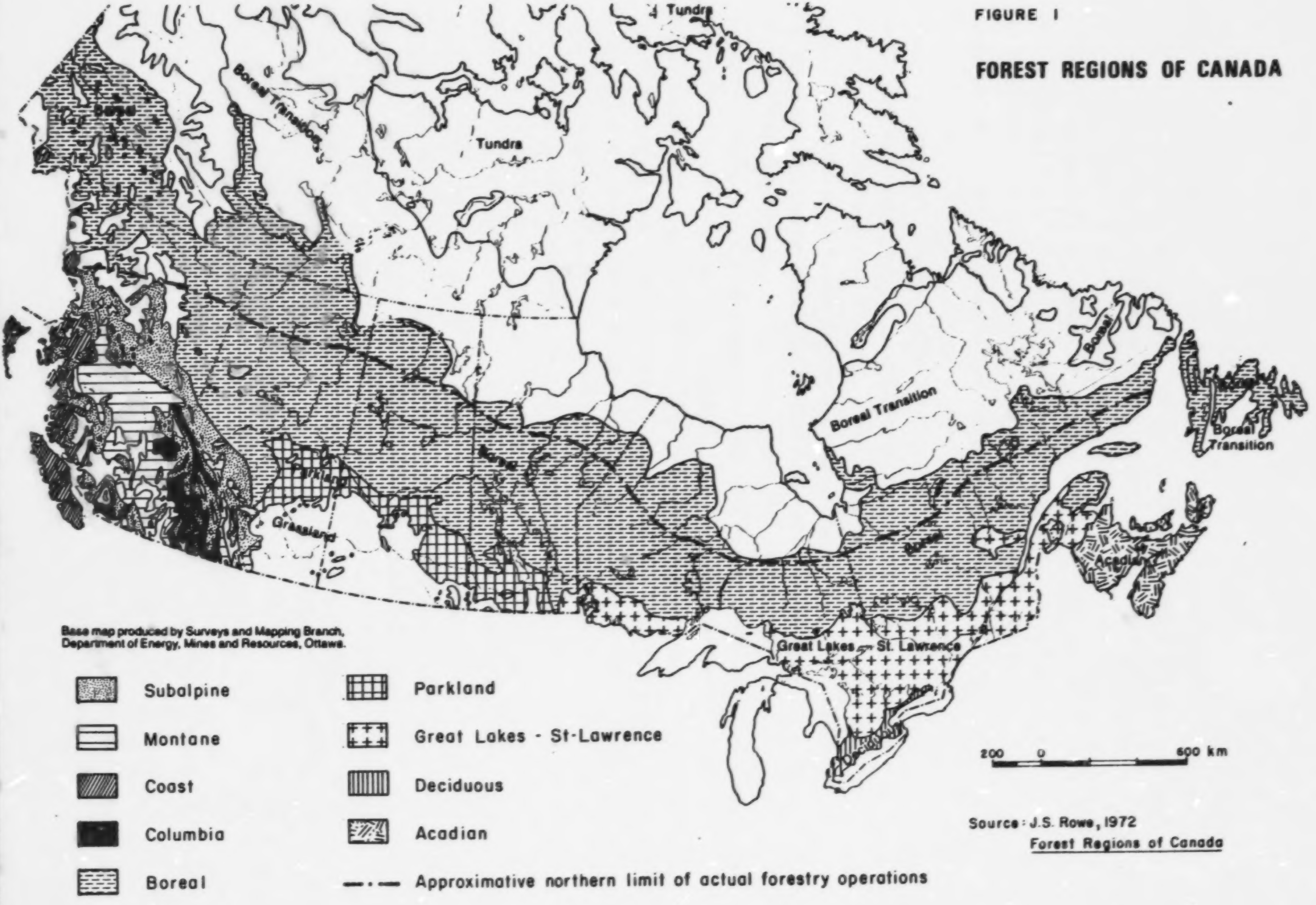
LOCATION AND DESCRIPTION OF THE FOREST REGIONS OF CANADA[1]

Name of forest region	Location	Main and secondary species	Remarks
Boreal	From Newfoundland to the Rocky Mountains and northwestward to Alaska.	- white spruce, black spruce - larch, balsam fir, jack pine, alpine fir and lodgepole pine. - white birch, trembling aspen, balsam poplar.	Greater part of the forested area of Canada
Acadian	New Brunswick, Nova Scotia and Prince Edward Island.	- red spruce, balsam fir - red pine, white pine, black spruce, hemlock, white spruce - yellow birch, sugar maple, beech, red oak, white elm - black ash, red maple, white birch, grey birch, trembling aspen, balsam poplar.	Forest closely related to the Great Lakes - St. Lawrence forest region and to a lesser extent, to the boreal forest region. For a detailed description, see Loucks O.L. 1962. A forest classification for the Maritime provinces.
Great Lakes - St. Lawrence Forest Region	Southern Québec and south-central Ontario.	Mixed forest characterized by: - white and red pine, eastern hemlock and yellow birch - sugar maple, red maple, red oak, basswood and white elm - beech, white oak, butternut and white ash - boreal species (aspen, spruces, fir, jack pine,...) are intermixed.	Much of these forests have been cleared for agricultural purposes mainly along the shore of the St. Lawrence river.
Deciduous	Southern Ontario.	- sugar maple, beech, white elm, basswood, red ash, white oak and butternut ash - northern limit of tulip tree, cucumber tree, pawpaw, red mulberry, Kentucky coffee tree, black gum, blue ash, sassafras.	Most of the land is now closely settled. Natural forest vegetation has been mostly reduced to farm wood lots, hedgerows and remnant stands on soils too poor to farm.
Parkland (boreal forest and grassland transition)	Southern Manitoba, southern-central Saskatchewan and eastern-central Alberta.	- trembling aspen, balsam poplar, (mossy-cup oak), cottonwood, green ash, Manitoba maple, white elm.	Large areas of parkland under cultivation.
Subalpine	Mountain uplands in western Alberta and in British Columbia.	- engelmann spruce, alpine fir, lodgepole pine	Found between 1 500 and 2 100 m (level) on the eastern slopes of the Rocky Mountains.
		Intrusion of spruces (black and white) and trembling aspen. Entry of interior Douglas fir, of coast amabilis fir, western hemlock and western red cedar,....	Found between 1 100 and 1 200 m (level) in interior eastern British Columbia. Over 900 m of elevation on Vancouver Island and on the western coast.
Montane	Central plateau of British Columbia and several southern mountain valleys adjacent to Alberta boundary.	- ponderosa pine, white spruce, western white birch, engelmann spruce, alpine fir, lodgepole pine, trembling aspen, blue form of Douglas fir.	Northern extension of the typical forest of much of the western mountain system in the United States.
Coast	Part of the Pacific Coast forest of North America.	- western red cedar, western hemlock, sitka spruce (north), coast Douglas fir (south), amabilis fir, yellow cypress, mountain hemlock, alpine fir, western white pine.	Arbustus and Garry oak occur in Canada on the southeast coast of Vancouver Island and the adjacent islands and mainland.
Columbia	In British Columbia in a large part of the Kootenay River Valley, the upper valleys of the Thompson and Fraser rivers, and the Quesnel Lake area.	- western red cedar and western hemlock - interior Douglas fir, western white pine, western larch, grand fir, western yew.	Contains a coniferous forest closely resembling that of the Coast Forest Region though less rich in species.

1. Source: Rowe, 1972, Forest Regions of Canada.

FIGURE I

FOREST REGIONS OF CANADA


Tundra
Tundra
Boreal Transition
Boreal
Boreal Transition
Boreal
Boreal
Transition
Boreal
Parkland
Grassland
Boreal
Boreal
Acadian
Great Lakes — St. Lawrence
Deciduous
Subalpine
Montane
Coast
Columbia
Boreal
Parkland
Great Lakes - St-Lawrence
Deciduous
Acadian
Approximative northern limit of actual forestry operations
200
0
600 km

Base map produced by Surveys and Mapping Branch, Department of Energy, Mines and Resources, Ottawa.

Source: J.S. Rowe, 1972
Forest Regions of Canada

Boundaries of these forest regions represent the biological limits of potential forest biomass production in Canada. However, practically, in order to reduce areas of investigation (fauna and flora), the deciduous forest regions have been subtracted. In fact, the Niagara peninsula is almost completely converted to agriculture and should keep this vocation (food production) even in the face of high demand for energy from the forests. The northern limit of this zone corresponds to the actual northern limit of forestry operations in Canada (Figure 1). This limit has been drawn according to information gathered from each province. Yukon and North West Territories are also subtracted because of low forestry activity, small local market, poor accessibility to other markets and competition from the British Colombia forest industry (Redpath, 1979). Most operations provide only supplemental income to employees... Many operations are portable or semi-portable, and all the main sawmills are in the southern portion of the Mackenzie district. There is one sawmill at Fort Simpson and Fort Resolution and two each at Fort Smith and Hag River (Fenge, 1979). These relatively untouched lands represent a wood and energy reserve for the future development of these northern regions. Northern Ontario, northern Quebec and Labrador are also excluded for the same reasons (low productivity and activity).

3.2- The management alternatives

A review of literature concerning forest management for biomass production, has rapidly demonstrated that there are actually no such activities undertaken on a large scale in Canada. Similar observations have also been noted by Dryade (1980) in a study aiming to evaluate potential impacts of forest biomass harvesting on general biophysical components. The quality of available information has however permitted the detection of tendancies as to what type of forest management would result when demand for biomass reaches a high intensity.

Telfer (1978) presented an overview of the situation, defining four possible alternatives in increasing order of intensity under what he called «Complete forest management»:

- Complete utilization
- Production of Native species on Short Rotations
- The «Energy Plantation» Concept
- Large monocultures of Exotics

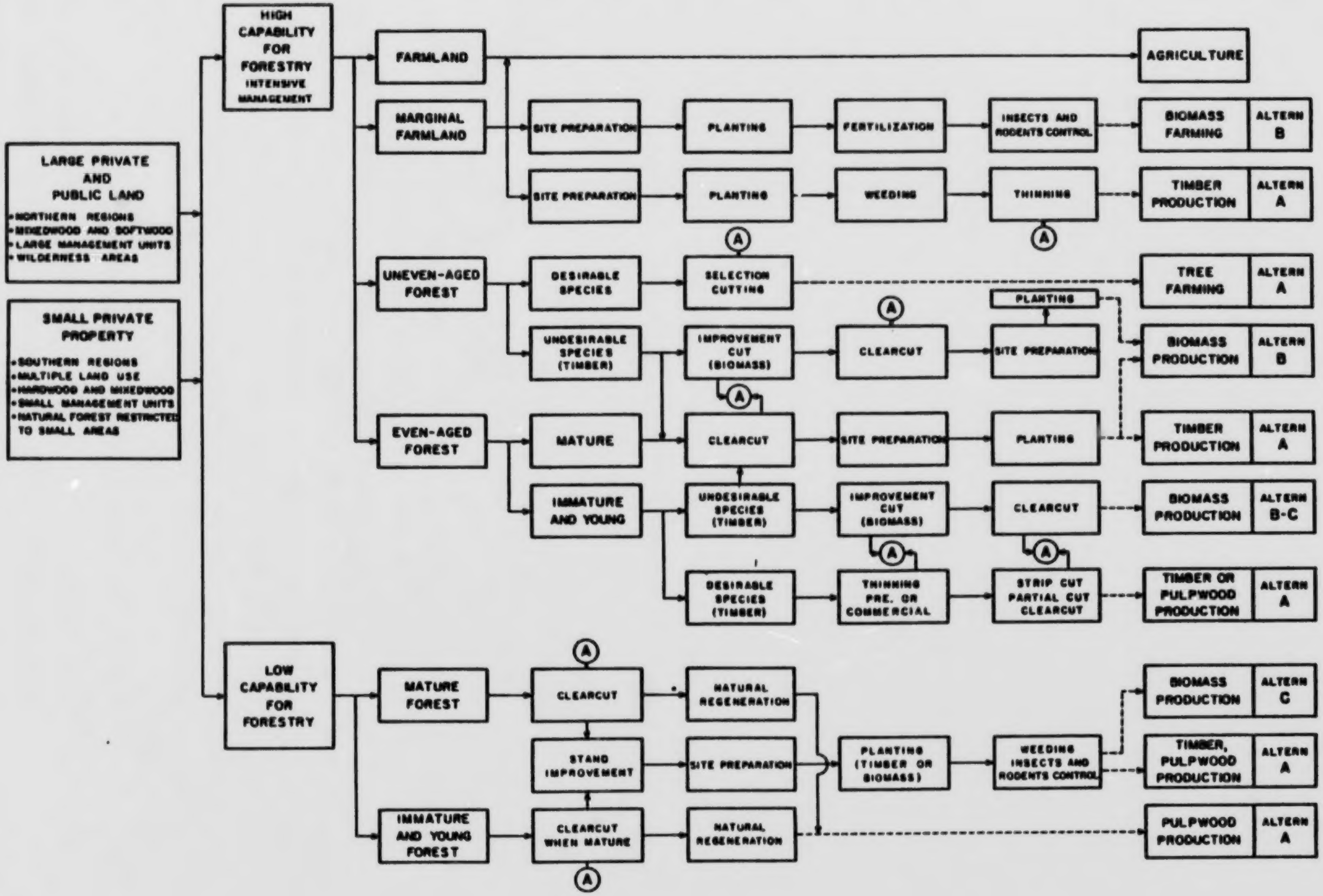
These alternatives still represent pathways for biomass production in Canada depending on economic and technical factors. In fact, the biomass production concept will develop along with other traditional forest and land activities. For example, complete utilization would be better associated with extensive logging operations while the «Energy Plantation Concept» would be practised in areas where the land is already capable of producing trees or other products on a high yield basis. The development of this rather new forestry concept will firstly have to integrate with traditionnal land use activities and then, secondly, to go along with economic fluctuations. Putting aside matters relating to the transformation of raw material and market evolution, Figure 2 illustrates how three biomass production alternatives might be implemented on large private and public lands and on small private properties. This figure only aims to illustrate the fact that biomass production could become an interesting opportunity for land managers but would have to be considered at different levels of activity. Those alternatives are described in the following section. Objectives of these descriptions, based on a literature review, are to identify management practices in order to produce realistic hypotheses of the type of forest landscape that would result in the various forest regions and provinces of Canada if management for energy production becomes common.

3.2.1- The Complete Forest Concept (Alternative A)

This alternative has been first described by Young at the University of Maine (1977). It comes from the principle that all

Figure 2. Organigram showing integration of biomass management alternatives on private and public land.

A: Complete Forest Concept; B: Short-Rotation Intensive Culture; C: Production of native species on short rotation.


LARGE PRIVATE AND PUBLIC LAND
•NORTHERN REGIONS
•MIXEDWOOD AND SOFTWOOD
•LARGE MANAGEMENT UNITS
•WILDERNESS AREAS
SMALL PRIVATE PROPERTY
•SOUTHERN REGIONS
•MULTIPLE LAND USE
•HARDWOOD AND MIXEDWOOD
•SMALL MANAGEMENT UNITS
•NATURAL FOREST RESTRICTED TO SMALL AREAS
HIGH CAPABILITY FOR FORESTRY INTENSIVE MANAGEMENT
LOW CAPABILITY FOR FORESTRY
FARMLAND
AGRICULTURE
MARGINAL FARMLAND
SITE PREPARATION
PLANTING
FERTILIZATION
INSECTS AND RODENTS CONTROL
BIOMASS FARMING
ALTERN B
SITE PREPARATION
PLANTING
WEEDING
THINNING
A
TIMBER PRODUCTION
ALTERN A
UNEVEN-AGED FOREST
DESIRABLE SPECIES
A
SELECTION CUTTING
TREE FARMING
ALTERN A
UNDESIRABLE SPECIES (TIMBER)
IMPROVEMENT CUT (BIOMASS)
A
CLEARCUT
SITE PREPARATION
PLANTING
BIOMASS PRODUCTION
ALTERN B
EVEN-AGED FOREST
MATURE
A
CLEARCUT
SITE PREPARATION
PLANTING
TIMBER PRODUCTION
ALTERN A
IMMATURE AND YOUNG
UNDESIRABLE SPECIES (TIMBER)
IMPROVEMENT CUT (BIOMASS)
CLEARCUT
BIOMASS PRODUCTION
ALTERN B-C
A
A
DESIRABLE SPECIES (TIMBER)
THINNING PRE. OR COMMERCIAL
STRIP CUT PARTIAL CUT CLEARCUT
TIMBER OR PULPWOOD PRODUCTION
ALTERN A
MATURE FOREST
A
CLEARCUT
NATURAL REGENERATION
STAND IMPROVEMENT
SITE PREPARATION
PLANTING (TIMBER OR BIOMASS)
WEEDING INSECTS AND RODENTS CONTROL
BIOMASS PRODUCTION
ALTERN C
TIMBER, PULPWOOD PRODUCTION
ALTERN A
IMMATURE AND YOUNG FOREST
CLEARCUT WHEN MATURE
A
NATURAL REGENERATION
PULPWOOD PRODUCTION
ALTERN A

biomass produced in the forest should be considered potential industrial raw material. In fact, forest exploitation has been conducted in the past, by cutting sound trees of a limited range of species and sizes. Species considered low quality and small trees and shrubs were ignored. The resulting harvest was often less than 15% of the biological productivity of the site (Telfer, 1978).

The expression, «Complete Forest Concept» incorporates all categories of woody material including merchantable wood and also material referred to as «biomasse excédentaire», «forest residues», to designate all woody or lignified matter abandonned on logged areas or treated stands; all non-commercial shrubs or trees, all non valuable forest stands as well as all residues (sawdust, bark,...) originating from mills.

To posit a hypothesis in our conceptual model, this first alternative is divided into three sub-alternatives: logging residues, low-grade forests and material harvested during silvicultural treatments.

3.2.1.1- Logging residues

A large amount of forest biomass remains on logged areas after clearcutting of merchantable trees. These residues usually comprise tops, branches, stumps, shrubs, non commercial, dead and dying trees. The amount of residues is highly variable depending of tree species, density, age of stand, logging method. For example, residues weighed in a mature black spruce stand in Northern Quebec after clearcutting using the tree-length method total 56,5 oven-dry tons/ha. Of the total 48% are tops, 21% branches, 28% trunks (green and dead) and 3% remnants and stumps (Laverdière, 1980). On Vancouver Island, a recent study (Jones, 1979) has shown that average sound volumes per hectare of logging residues varies from 58 m^3 on a low site Douglas Fir area to 615 m^3 on a highsite rocky Red Cedar (including only material 8 cm and over). The average volume per hectare was 222 m^3. The average volume of sound and rotten wood per hectare was 18% higher at 262 m^3.

Actual data does not permit the evaluation of the amount of residues easily available for energy conversion in Canada. Dobbs (1979) noted that inventories represent a static condition for the forest area. Growth, or biomass accretion, renders the data obsolete. Biomass yield tables will be required to provide total biomass per unit area and its distribution among tree and stand components at different stand ages. Accumulation of such information for natural stands alone is a formidable task. In addition, biomass yield data is required for stands under varying complexities of management planning.

In our general model, the extension of this sub-alternative will be closely related to actual logging operations in Canada. This will permit specification of the type of landscape that could result if removal of logging residues becomes a common practice. In fact, clearcutting represents the first and sometimes unique management possibility for mature and overmature even-aged stands.

Harvesting systems applicable to clearcutting with recovery of residues have been discussed in the ENFOR Project P-15 (Weldwood, 1979). In this report, four harvesting systems are described which all could be applied to the Canadian forest regions except for specific conditions (slope) in southwestern Alberta and British Colombia:

1. Harvesting residuals together with stem wood: full-tree logging with crown and slash reaching the landing as byproducts of the system. The greatest problem of this system is the high production of branch material lost due to breakage in skidding (losses from 30 to 50%) (Elovainio, 1976).

2. Harvesting of branch wood from the cutting area after removal of stem wood, chipping at primary landing: several steps occur between stump and landing:

- bunching in the cutting area
- loading into a hauling unit
- forwarding and unloading at the landing

These operations could be done with current short-log forwarders or farm tractors equipped with a suitable grapple.

The greatest problem is a low branch load density of 60 to 120 kg per m^3. Three alternatives are noted:

- compaction (baling) prior to loading,
- compacting the load during loading or hauling
- increasing the load space.

In Sweden, the greatest success was obtained by widening or lengthening the normal load space; the load compacted under its own weight (Eleovainio, 1976).

3. Harvesting of branchwood from the cutting area after removal of stemwood, chipping at the stump: the bunching operation is similar to that noted above except that bunches should be larger. Chipping offers no problems but should be coordinated with chip transportation (Eleovainio, 1976). It was stated that, in Sweden, neither chipping nor mechanical compaction at stump were economical (Joint Committee of the Forest Industries, 1977).

4. Harvesting of branch wood and transport to mill: Compaction of the loads is mandatory for any hauling distance exceeding 30 km (Joint Committee of the Forest Industries, 1977).

The first system will probably be most commonly used in Canada but will require a large landing area, and breakage losses are considerable. Other systems afford a better yield, but compaction problems are not yet solved (Eleovainio, 1976 and Hansen, 1975).

In coast forests of British Columbia, Nagle (1980) concludes that new technology will be required to extract about 50% of available residuals at any likely economic price and nearly 2 million bone-dry tons are likely available at roadside with minor modifications to present systems. Nagle also stated that one approach offering some promise is the slashing or snipping of forest residues into small blocks (e.g. 0,5 m long) in the landing, followed by belt-loading into vans for hauling.

3.2.1.2- Cull or low-grade stands

Low-grade stands represents another important actual unused source of forest biomass (Lévesque, 1980). Present forest industry only use a few species of trees, mainly softwoods because of market conditions (quantity and quality). Consequently, stands comprising low volume of desirable species are not economically valuable and are considered as low-grade.

These forests are generally second growth stands mainly composed of intolerant hardwoods such as poplars, birches, maples, alder,... Most of these forests are located in the vicinity of urban centres and localities. They have been logged many years ago and have regenerated naturally, becoming stocked with species undesirable for existing markets. As a matter of fact, these stands are growing on our best forest lands and should be managed to produce high quality products. In a maximum production management context, it is urgent to improve forest on these lands in order to ensure permanent supplies to our mills. In most provinces, planting programs are covering more and more areas each year. A realistic solution would be to remove the low-grade existing stands and to use this raw meterial for energy conversion to help offset planting costs. In our general model, new stands would be established and would comprise biomass production as well as timber or pulpwood production.

Logging systems will largely depend on the content of valuable species and diameter of trees (Lévesque, 1980). In many cases, it will be most economical to harvest timber and pulpwood first, and residues, second. Whenever the quality of trees is too low, biomass logging will be done in one step using specialized machinery such as swathers combined with chippers. However, in all cases there will be no residues left on the ground neither standing, dead, dying nor formerly undesirable trees or shrubs.

3.2.1.3- Residues from silvicultural treatments

Residues from silvicultural treatments represent another possible source of forest biomass. In our general model, treatments considered could include all special cuts (shelterwood, conversion, sanitation) and treatments such as spacing, cleaning and thinnings (pre-commercial and commercial) in which there are possibilities of recovering biomass. These treatments would be practised in areas where natural second growth consists of species valuable for timber, pulpwood or biomass production. In all cases, harvesting systems will have to protect the remaining stand.

This aspect of biomass production is not yet documented in literature. An ENFOR study (Jones, 1979) on Vancouver Island has reported that in thinning operations being carried out today, 1200 to 10 000 trees are felled per hectare. The great variation in number of trees felled relates to the large differences in stand ages, site and stocking... However, the average volumes per tree are extremely low (0,002 m^3 for a 13-year old stand). In the Sayward forests of Vancouver Island, a typical stand being treated is 24 years old and contains 2 000 trees per hectare, with 1 400 to be removed. The average volume per tree of the 1400 trees being felled is 0,04 m^3 or 56 m^3 per hectare.

Smith and Sziklai (1979) have demonstrated the effect of spacing on the above-ground biomass yield of red alder. Natural stands on medium sites could yield an average of about 7,6 oven-dry tons per ha per year on a 10-year rotation. By control of spacing through thinning, to leave as few as 400 trees per ha, approximatively 6,7 tons per ha could be removed annually for low value uses (e.g. energy production). There would remain at the end of the 10-year period about 8,4 tons per ha as a foundation for fast growth of trees to the large sizes desired for lumber or veneer.

Main problems encountered in harvesting residues from spacing and thinning operations are high direct logging costs, high manpower costs and requirements, and finally damage to the remaining stand (Weldwood, 1979). Interesting approaches have been developped in Northern Europe. Mechanized thinning (mechanical delimber and topper, brush harvester, field chipper,...) on a row or corridor basis, represent realistic solutions to problems (Weldwood, 1979).

Other silvicultural treatments such as improvement cuts could represent another source of biomass. The most characteristic situation is a two-story stand composed of 40 to 50-year old intolerant hardwood species (poplars, birch) growing on top and a well stocked young softwood stand (fir, spruce) growing underneath. Elimination of the upper layer definitively stimulates the young softwoods. The operation, if properly done, stimulates the growth of residual softwood and a significant volume of biomass could be removed to cover the cost of the operations. Damage to the residual trees could contribute additional spacing in order to reduce number of residual stems per hectare.

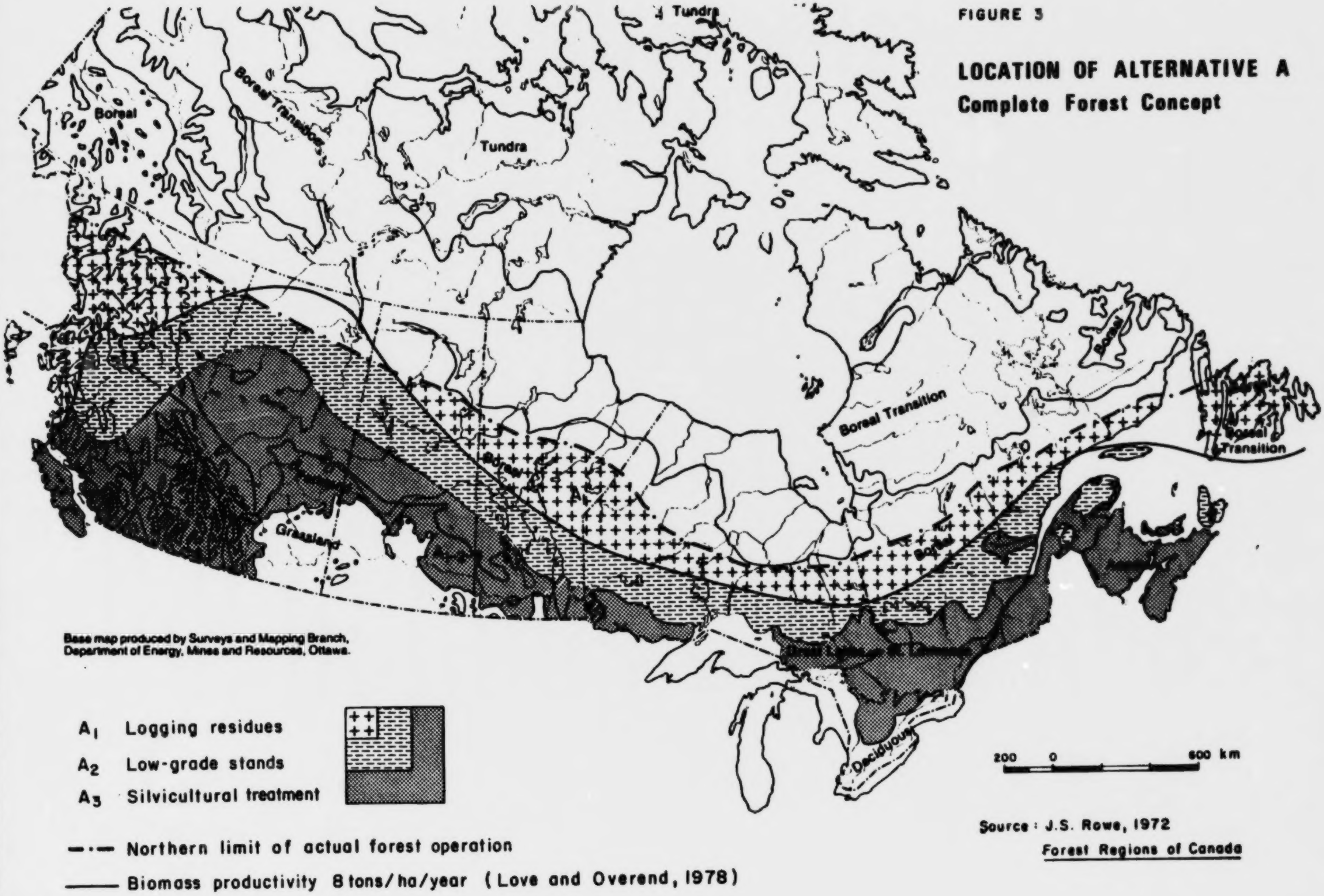
3.2.1.4- Area of application

The complete Forest Concept could be developped in all provinces of Canada. Figure 3 illustrates probable location of this first alternative. In the northern part of the boreal forest region, where biomass productivity is likely below 8 tons/ha/year (Love and Overend, 1978) this alternative is limited to logging residues from harvesting operations.

In the southern part of the boreal forest region, where biomass productivity is over 8 tons/ha/year, two alternatives are likely to be worthwhile: recovery of residues in conventional logging

FIGURE 3

LOCATION OF ALTERNATIVE A
Complete Forest Concept


Tundra
Tundra
Boreal
Boreal Transition
Boreal Transition
Boreal
Boreal
Boreal
Boreal
Boreal Transition
Grassland
Deciduous
A1
A1 Logging residues
A2 Low-grade stands
A3 Silvicultural treatment
Northern limit of actual forest operation
Biomass productivity 8 tons/ha/year (Love and Overend, 1978)
200 0 600 km

Base map produced by Surveys and Mapping Branch, Department of Energy, Mines and Resources, Ottawa.

Source : J.S. Rowe, 1972
Forest Regions of Canada

operations and clear-cutting low-grade hardwood or softwood stands.

In other forest regions, including the mixed wood part of the Boreal Forest Region (central Saskatchewan and Alberta), the Parkland, most of the forest regions of British Columbia (Coastal, Montane, Columbia), the Great-Lakes - St. Lawrence and Acadian, salvage of residues from silvilcultural treatments could also represent a realistic alternative.

Extension of the latter alternative should be closely related to actual logging operations. This level of activity is defined in table 3 which gives for each province approximate annual allowable cut and annual depletion by cutting. These 1976 statistics, published in 1978 (Bowen, 1978), demonstrate that for all provinces, the total annual depletion by cutting covers half of the total annual allowable cut. However, this ratio is not evenly distributed in all provinces. Nova Scotia, New Brunswick, Quebec and British Columbia are cutting more than half of the allowable cut while this ratio is not attained in other provinces. These latter provinces (Newfoundland, Ontario, Prairie Provinces) could increase annual cut and extend operations to new territories without depleting the resource. At the opposite, British Columbia, Quebec and the Maritimes Provinces would face a deficit within the next four to five decades if logging activities keep at present level.

Logging low-grade stands and residues from silvicultural treatments should be first undertaken in provinces where a deficit in wood availability is foreseen.

In the context of maximum forest biomass production, the logged areas (formerly mature, overmature and cull stands) will be restocked for timber, pulpwood or biomass production or converted to other uses. In fact the most productive lands should be intensively managed while low productivity lands should be

Table 3. Annual allowable cut and annual depletion by cutting from productive forest land

	Nfld.	N.S.	N.B.	Que.[1]	Ont.	Man.	Sask.	Alta.	B.C.	Total
Annual allowable cut (000 m^3)										
Crown	4 955	1 132	6 939	33 880	54 508	7 610	8 156	28 170	93 447	238 797
Private	453	2 726	6 801	6 900	11 532	-	-	-	5 942	34 354
All ownerships	5 408	3 858	13 740	40 780	66 040	7 610	8 156	28 170	99 389	273 151
Annual depletion by cutting										
Crown: volume (000 m^3)	2 252	614	3 764	18 307	14 708	1 855	2 236	4 797	61 237	109 860
area (km^2)	257	-	-	-	1 967	214	179	202	1 377	4 196
Private: volume (000 m^3)	371	2 621	3 528	6 655	-	-	-	-	8 360	21 535
area (km^2)	40	-	-	-	-	-	-	-	189	229
All ownerships: volume (000 m^3)	2 623	3 235	7 292	24 962	14 708	1 855	2 236	4 797	69 867	131 395
area (km^2)	297	-	-	-	1 967	214	179	202	1 566	4 425

Source: Bowen (1978).

[1] Data are for only that portion of Quebec's forest inventory that was compiled when the table was prepared. The data on about 179 000 km^2 of forest land remaining in the «forest management inventory» are expected to be available by the end of 1978.

extensively managed. In this first alternative, highly productive land will be restocked with valuable species for timber (hardwood or softwood) or pulpwood. Management for biomass production will be considered in the next 2 alternatives (Short Rotation Intensive Culture and Production of Native Species on Short Rotation). Lands of low productivity will be either improved (e.g. land drainage) where feasable and restocked with valuable species, or left to grow freely. Rotation will be likely longer for the second case and much shorter in the first case. In fact, intensive management should occur in the best land and the following practices could be undertaken:

- site preparation (chemically or physically)
- stand establishment (natural regeneration, seeding, plantation)
- fertilization
- weed control (chemically)
- spacing
- thinning with recuperation of residues
- harvesting when mature, with recuperation of residues

3.2.2- The Short Rotation Intensive Culture

The Short Rotation Intensive Culture (SRIC) is a rather new agriforestry concept originating from the following principle: Is it worthwhile to produce trees 30 cm and over in diameter to make chips, fiber or even cellulose, methanol, energy,...? Why not produce maximum biomass in the shortest time in order to exploit productive capacity of soils and solar energy reaching the ground by surface unit? Using advanced cultural techniques, the method consists in achieving rapid coverage of all the managed surface with a leaf canopy and filling all the productive soil volume with roots to produce economically profitable and usable biomass (Vallée, 1979).

Since 1960, following such principles, researches have elaborated different strategies for culturing fast growing trees. Of all the provinces of Canada, Ontario and Québec are the most involved in this field of research. Of all the potential fast growing species (Table 4), genus Populus has been well studied in the past 20 years. Lately, genus Betula and Salix are subjects of research.

All the production stressing strategies stated in literature, contain common features: complete man-made high density plantations located near urban centres or mills in order to reduce transportation costs. In our general model, areas suitable for such utilization comprise marginal farmlands and logged areas.

For example, southeastern Ontario is a region of 2,5 million hectares of which 25% has dropped out of agricultural production and currently supports no worthwhile crop (Raitanen, 1980). These lands, because of imperfect drainage and the heterogeneous nature of the soil, offers excellent conditions for intensive culture of forest biomass (Raitanen, 1980).

Three management systems are presently identified: mini rotation, midi rotation and short rotation. Table 5 gives main characteristics of these systems applied for hybrid poplars:

Table 5: Density, rotation and near productivity of SRIC management systems

Management systems	Density (stems/ha)	Rotation (year)	Mean productivity (oven-dry tons/ha)
Mini rotation	35 000	2	15
Midi rotation	4 300	5	8
Short rotation	1 000	10	6,5

(Raitanen, 1980).

Each of the management systems must involve a series of activities which comprises (Raitanen, 1980):

Table 4

Potential species for short rotation intensive culture

SPECIES	Establishment		Regeneration		
	Cuttings	Direct sowing	R	D	E[1]
Hardwood					
Acer saccharinum		X	X		
Acer negundo		X	X		
Alnus x spp.		X	X		
Alnus crispa		X	X		
Alnus rugosa		X	X		
Alnus rubra		X	X		
Alnus glutinosa		X	X		
Gleditsia triacanthos	X	X	X		
Betula papyrifera		X	X		
Fraxinus pennsylvanica		X	X		
Populus x spp.	X	X	X	X	
Populus alba	X	X	X	X	
Populus balsamifera	X	X	X	X	
Populus deltoides	X	X	X		
Populus nigra	X	X	X		
Populus tremuloides		X	X	X	
Populus trichocarpa	X	X	X	X	
Populus grandidentata		X	X	X	
Robinia pseudo-acacia	X	X	X	X	
Salix x. spp.	X	X	X		
Salix nigra	X	X	X		
Salix alba	X	X	X		
Salix amygdaloides	X	X	X		
Salix fragilis	X	X	X		
Ulmus americana		X	X		
Ulmus sibirica		X	X		
Softwood					
Larix laricina		X			X
Larix leptolepis		X			X
Larix decidua		X			X
Larix eurolepis		X			X
Pinus banksiana		X			X
Pinus sylvestris		X			X

[1] R: shoots
D: suckers
E: seeds

Source: Vallée (1979).

- site preparation
- weed control
- planting operation
- harvesting
- drainage
- subsoiling
- fertilization

The resulting raw material could be used to either produce energy, ethanol, methanol or other derived products. For example to provide a 50 megawatt power generating plant, 20 000 ha of mini rotations poplar plantations will be necessary. Table 6 enumerates for the three management systems (mini, midi and short rotations) total area required to provide raw material for different utilizations.

Table 6: Total area required to provide raw material for potential utilization.

	Mini rotation (ha)	Midi rotation (ha)	Short rotation (ha)
Power generation (50 MW)	20 000	35 000	50 000
Ethanol (450×10^6 litres/year)	110 000	215 000	280 000
Methanol (450×10^6 litres/year)	75 000	135 000	170 000
360 000 oven-dry tons/year	24 000	43 000	56 000

Within a 40-km radius of a mill site, there are 508 000 ha. If 50% of this area is suitable and available for silvicultural biomass farming, we would have 254 000 ha. The organization of feedstock supply must then involve many land owners in areas where marginal farmlands are abundant and involve large plantations on logged areas of public lands (usually on soil of high capability for forestry).

The intensive culture of fast growing trees could be undertaken at different levels in every province of Canada. Figure 4 illustrates where it could be feasable. Generally speaking, this second alternative would be intimately associated to marginal farmland and logged areas in the vicinity of urban centres. These areas are mainly concentrated in the southern part of each province where agricultural lands occurred, with the exception of British Columbia and Newfoundland where these lands represent less than 3% of the total land base. All other provinces have a proportion of farmland which could be suitable for such purpose. Table 7 enumerates for each province areas of farmland and changes since 1921. At the national level, the area of total farmland which includes improved and unimproved land, has generally increased between 1921 and 1976. However, in the central and eastern provinces, total area has steadily declined since 1921. The net loss was 95 428 km^2 while the net gain for the Prairie provinces and British Columbia was 196 918 km^2. So marginal farmlands suitable for SRIC are more available in central and eastern Canada than in the western provinces.

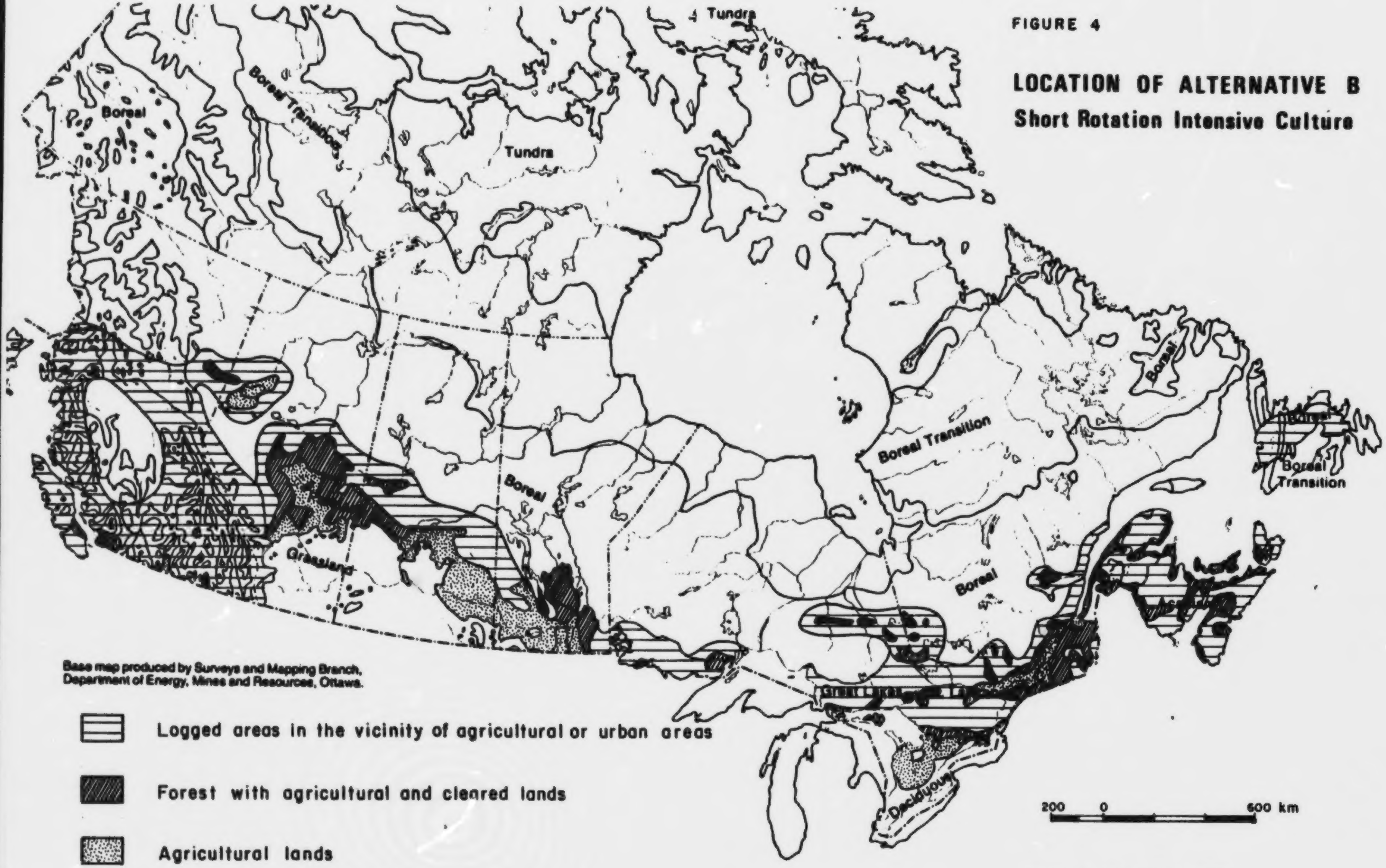
In the Prairie Provinces, agriculture is still advancing onto wildland. For example, in the Peace River district located on the border of Alberta and British Columbia in the northern part of these provinces, there are 81 000 km^2 of land potentially suitable for agriculture of which 20 250 km^2 are actually cultivated (Beattie et al., 1981).

Underutilized lands of south-eastern Saskatchewan and eastern Manitoba could also offer an excellent potential. Other land could also be available in the northern part of those provinces (Beattie et al., 1981).

FIGURE 4

LOCATION OF ALTERNATIVE B

Short Rotation Intensive Culture


Tundra
Boreal
Boreal Transition
Tundra
Boreal
Grassland
Boreal Transition
Boreal
Boreal
Boreal
Boreal Transition
Great Lakes St. Lawrence
Deciduous
200
0
600 km

Base map produced by Surveys and Mapping Branch, Department of Energy, Mines and Resources, Ottawa.

▤ Logged areas in the vicinity of agricultural or urban areas

▨ Forest with agricultural and cleared lands

░ Agricultural lands

Source : J.S. Rowe, 1972
Forest Regions of Canada

Table 7. Area of total farmlands by provinces (1921, 1951 and 1976).

Province	Area of farmland (km^2)			Changes	
	1921	1951	1976	km^2 (1921-1976)	%
Newfoundland		344	294	-	-
Prince Edward Island	4 923	4 433	2 780	- 2 143	- 43
Nova Scotia	19 116	12 843	4 002	- 15 114	- 80
New Brunswick	17 279	14 044	4 023	- 13 256	- 77
Quebec	69 839	67 935	36 541	- 33 298	- 48
Ontario	91 579	84 502	59 668	- 31 911	- 35
Manitoba	59 150	71 755	76 110	+ 16 960	+ 29
Saskatchewan	178 160	249 551	264 326	+ 86 166	+ 48
Alberta	118 549	179 928	200 400	+ 81 851	+ 69
British Columbia	11 577	19 030	23 518	+ 11 941	+ 103
Total	570 172	704 365	671 662	+101 490	+ 18

Source: Simpson - Lewis *et al.* (1979).

3.2.3- Production of Native Species on Short Rotation (Alternative C)

This third alternative consists in managing native species on a short rotation basis. Short rotation means, under Canadian conditions, anything less than 40 years (Telfer, 1978). Suckering, sprouting, high density regeneration of undesirable species after clearcutting, fires or other natural disasters are the essence of this alternative. Species involved are diversified and some occur in each forest region of Canada. Poplar, birch, willow, alder, maple, ash, elm, fir, spruce,... are all species that have the ability to regenerate prolifically either by suckering, sprouting of seeding. A recent study (Peterson, Levson and Kabzems, 1980) indicated that within 10 years from the date of stand establishment, most tree or shrub species that characteristically occupy disturbed sites can achieve standing crop densities (biomass/m^3) up to their mean stand height at least equal to those of mature forest stands.

A species which represents a very interesting avenue for short rotation is poplar in natural stands. Table 8 gives an estimate of the poplar resource in Canada (Zsuffa, Bouffard and Llegat, 1979). These wood volumes comprise approximatively 54% of the total volume of all hardwoods and 9% of the combined volumes of hardwoods and softwoods. Table 9 presents an estimate of the actual utilization of poplar in Canada. These numbers compared to the resource demonstrate that poplar is underexploited.

In our general model, we will consider simple management activities for this resource which could be extrapolated to all species growing on disturbed sites:

- clearcut of undesirable immature and mature stands;
- stimulation of root-suckering, sprouting and seeding, to ensure abundant regeneration;
- planting if necessary;

Table 8

Natural Poplar Resource - Wood volumes in Canada's forest inventory 1976[1] (million m^3)

Provinces	On crown land				On private land		
	Accessible			Inaccessible			
	Immature class	Mature class	Total	All classes		Total	%
Newfoudland	1	3	4			4	-
Prince Edward Island						N/A	-
Nova Scotia			1		4	5	-
New Brunswick	2	8	10		21	31	1
Quebec	66	144	210	3	20	233	11
Ontario	268	367	635	77	84	796	37
Manitoba	38	80	118	41	5	164	8
Saskatchewan	41	132	173	15		188	9
Alberta	498	93	591			591	27
British Columbia		71	71	55	6	132	6
North West Territories						N/A	-
Yukon		9	9	18		27	1
Canada - Total	914	907	1 822	209	140	2 171	100
Canada - Total - %	42	42	84	10	6	100	

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[1] Bowen, M.G., 1976. Canada's forest inventory.

Table 9

Commercial Poplar Utilization in Canada

Provinces	Total Utilized (million m^3)	Percentage distribution of utilized volume					
		Pulp and Paper					
		Domestic mills	Pulpwood export	Plywood	Particleboard	Sawmills	Fuel wood
British Columbia	0,1	100%					
Alberta	0,12				21%	46%	33%
Saskatchewan	0,6				80%	20%	
Manitoba	0,06		52%			18%	30%
Ontario	1,9	35%		30%	30%	5%	
Quebec	0,75	80%		13%		7%	
New Brunswick	0,085	96%					4%
Nova Scotia	0,1	65%			25%	5%	5%
Prince Edward Island	N/A						
Newfoundland	N/A						
Canada - presently	3,715	35%	7%	15%	27%	9%	7%
Canada 1965	2,1	58%	10,5%	13%	12%	6,5%	-

Source: Zsuffa, Bouffard and Leggat (1979).

- harvesting (clearcut) on a short rotation basis (< 40 years).

Location of this third alternative would be closely related to disturbed sites associated with man's activities (unimproved agricultural land, logged areas fully restocked with undesirable species; powerline right-of-way), natural high yield shrub and trees areas (alder, willow,...). As there are no actual survey for this alternative, areas covered would be the same as under alternative A (figure 2) with the exclusion of the zone of biomass productivity below 8 tons/ha/year in the boreal forest region.

4.- WILDLIFE OF CONCERN

All of Canada's surface area may be considered as wildlife land capable of maintaining a variety of plants and animals. Each species contributes to the ecological diversity of the country and represents an important part of our natural heritage.

Many factors influence the use of land by wildlife: vegetation including trees, topography, and climate interact to supply the food, water and shelter needed by each species. Increasing human pressure on wildland contributes to modification of habitats and consequently to changes in the diversity and density of wildlife population. Alteration of habitats is sometimes so drastic that some species vanish from a region because they do not find suitable habitat conditions to fulfill their vital needs. At the same time other species can be favored by these modifications and, without natural competition, could become prejudicial to man.

In this project, emphasis has been put on species that are either highly sensitive to man's disturbance (rare, threatened and endangered), representing a commercial or recreational value and on species that could be prejudicial to managed forests (pests other than insects). This selection has been done because of the large territory covered and otherwise the large number of species involved.

4.1- Selection of species

4.1.1- Sources of information and definition

4.1.1.1- Rare, threatened and endangered species

By the beginning of the 1970's, the status of 92 species and sub-species of mammals, birds, reptiles, amphibians and fish were so critical that biologists of the Canadian Wildlife Service and of the National Museum of Canada have given a special status to these animals. They then published a first list of rare and endangered species:

- Mammals: N.S. Novakowski; Canadian Wildlife Service

- Birds: W.E. Godfrey; National Museum of Canada
- Reptiles and Amphibians: F.R. Cook; National Museum of Canada
- Fish: D.E. McAllister; National Museum of Canada

Stewart (1974) has regrouped part of the known information in one book entitled «Canadian Endangered Species». In 1977, federal and provincial governments created a specific Committee On the Status of Endangered Wildlife In Canada (COSEWIC). Proceeding of the Symposium on Canada's Threatened Species and Habitats edited by Mosquin (1977), opinions and papers gathered in some provinces and obtained from independant organizations have permitted the establishment of a preliminary listing for each province. A comparison of the distribution of selected species to areas where forest biomass would be produced has permitted a first screening. Consequently species that inhabit only southern Ontario (Niagara peninsula), grassland of the prairie provinces, Yukon and North West Territories, northern Ontario and Québec (Figure 1), have not been considered.

Main problems encountered in the choice of rare, threatened and endangered species are:

. Authors do not use the same definition for their classification (Table 10).

. Some species classified as rare, threatened or endangered by one author are sometimes classified by another author or provincially as being a game species.

For example, the Grizzly bear and Mountain lion classified rare and threatened by Novakowski (1970), are game species in British Columbia. There are no absolute contradiction in these classifications. They are rather different opinions which are not necessarily based on same criteria. Species considered as rare,

TABLE 10: DEFINITIONS OF RARE, THREATENED, ENDANGERED, PERIPHERAL,...USED BY DIFFERENT AUTHORS

AUTHOR	RARE OR SPECIAL SPECIES	THREATENED SPECIES	ENDANGERED SPECIES	PERIPHERAL SPECIES	UNDETERMINED (Not in any category)
Cook (1977)	Undefined	Undefined	Undefined		
Cosemeq (1981)	List of species that should be studied to specify status.				
Cosewic (1981)	Rare species: Any indigenous species of fauna or flora that, because of its biological characteristics, or because it occurs at the fringe or its range, or for some other reason, exists in low numbers or in very restricted areas in Canada, but is not a threatened species.	Threatened species: Any indigenous species of fauna or flora that is likely to become endangered in Canada if the factors affecting its vulnerability do not become reversed.	Endangered species. Any indigenous species of fauna or flora whose existence in Canada is threatened with immediate extinction through all or a significant portion of its range, owing to the action of man.		
Gilhen and Scott (1981)	Description of limiting factors, do not classify.				
Godfrey (1970)			. Some species that are now, or soon may be, seriously imperiled. . Species are a number of others whose populations in Canada are so small that their continued existence in this country might be regarded as potentially precarious.		Many species regrouped by author and not having a particular status have been classified under this category.
Goodwin (1977)	. Some species have virtually their entire world breeding population in this country. Where that population is relatively limited geographically, and is perhaps a naturally small population to begin with, then the species is vulnerable. . Some colonial species at the end of aquatic good chains. . A widely but thinly distributed raptor species. . Species which are at the edge of natural ranges in Canada. . Species believed to be declining for other reasons.				
Gregory (1977)		. Species which are rarely abundant locally even under optimum conditions. These species may therefore be very sensitive to detrimental effects. . Species which have rather specific habitat and/or food requirements which may be lost as a result of human activity. . Species which are actively destroyed by humans because they are venomous, resemble venomous snakes, or are relatively large. . Species which are basically relict in Canada; their ranges barely extend into this country. Populations are probably very small and therefore sensitive to disturbance.			Species which may or may not be abundant in certain areas: status unkown.

TABLE 10: DEFINITIONS OF RARE, THREATENED, ENDANGERED, PERIPHERAL,...USED BY DIFFERENT AUTHORS (cont'd)

AUTHOR	RARE OR SPECIAL SPECIES	THREATENED SPECIES	ENDANGERED SPECIES	PERIPHERAL SPECIES	UNDETERMINED (Not in any category)
McAllister and Cruchy (1977)	Undefined.	Undefined.	Undefined.		
Min. of Environment-British Columbia (1979)	Special - populations maintaining themselves but which require regular surveillance because of small numbers or restricted habitat.	Threatened - declining or reduced populations not endangered at present, but which will become so unless protective or enhancement measures or both are initiated.	Endangered - populations immediately facing extinction in B.C. and requiring special protective or enhancement measures or both to ensure their survival.		Indeterminate - populations which are generally suspected of being threatened or endangered but for which information is too limited to allow designation in another category.
Nero and Wrigley (1977)	RARE - A species or subspecies which, although not presently threatened with extinction, is in such small numbers throughout its range that it may be endangered if its environment deteriorates. Close watch of its status is necessary.		ENDANGERED - A species or subspecies whose prospects for survival and reproduction are in jeopardy. Its peril may result from one or many causes - loss of habitat, overexploitation, predation, competition, disease, poisoning. An endangered species must have help, or extinction will probably follow.	PERIPHERAL - A species or subspecies whose occurence in Manitoba is at the edge of its natural range and which is rare or endangered within Manitoba, although not in its range as a whole. Special attention is necessary to assure its retention in the fauna of Manitoba.	
Novakowski (1970)	Rare species either occupy an extremely restricted habitat or are low in numbers.		Endangered species, were once either abundant or generally well distributed throughout Canada and are now being threatened by destruction of habitat or by deliberate attempts to eliminate them.	Peripheral species are distributed on the periphery of Canadian territory and thus may appear rare to Canadians.	
Stewart (1974)	Undefined.	Undefined.	Undefined.	Undefined.	Many species regrouped by author and not having a particular status have been classified under this category.

threatened, endangered in this study are a mixture of opinions. However, each author or specialist agree that those species are more vulnerable or sensitive to habitat modifications either due to natural behavior, habitat requirement or from a low tolerance to man's presence and activities. That is mainly why they have been retained for the evaluation of interactions with biomass production.

In 1973, the Systematics and Phytogeography Section of the Canadian Botanical Association formed a Rare and Endangered Plants Committee charged with making an inventory of the rare and endangered plants of Canada. As part of this effort, the National Museum of Natural Sciences initiated a project to assemble data on rare plants leading to the publication of a list for each of the provinces and territories. Lists are now available for most of the provinces except Prince Edward Island. A first analysis of these listings has permitted the selection of species directly or indirectly related to forest habitats. It has also permitted us to establish that information included in the listings do not allow further interpretation without more specifications of ecology and distribution. These listings are confined in Appendix II.

4.1.1.2- Recreational and commercial species

The use of wildlife has been an integral part of the development of Canada. Fur trapping and recreational hunting, historically the major uses of wildlife, have been primary concerns of wildlife managers. Wildlife provided the resource basis for the initial economic development of Canada. Wildlife still represents an important source of revenue for trappers and hours of enjoyment for hunters and fishermen. The indirect value of this renewable resource is still unmeasurable.

Species involved in this category are classified under Big Game, Small Game, Fur bearers, Waterfowl, Angling and Commercial fish.

- Big Game, Small Game and Waterfowl

The use of wildlife as a renewable resource generates an important commercial and recreational activity in Canada. The British North America Act of 1867 made no mention of wildlife but assumed that wildlife, like the other natural resources, would be the responsability of the provinces. Later, the signing of the Migratory Birds Convention Act in 1917 gave the federal government authority over the harvest of migratory birds. Since then, an increasingly complex matrix of licensing, hunting seasons, and bag limits has affected the hunting of wildlife. At the same time, the establishment of a national network of parks, sanctuaries, and reserves has supported the maintenance of wildlife habitat (Simpson-Lewis *et al.*, 1979).

In 1975, more than 2,5 million hunting licences were issued, generating a revenue of $18,1 million (Table 11) to federal, provincial and territorial wildlife agencies for big game, upland game, small game and migratory birds. Although the specific definition varies from province to province, in general, big game consists of moose, deer (white-tailed, black-tailed and mule), pronghorn, caribou, elk, mountain sheep, mountain goat, bison, bear (brown, black, polar and grizzly) and cougar. Small game includes rabbit, hare, squirrel, fox, coyote, wolf and wolverine. Upland birds are dominated by pheasant, grouse, partridge, quail and ptarmigan. Migratory birds include duck, geese, snipe, woodcock, gallinules, rails, coots, Sandhill Crane, Morning Dove and Band-tailed Pigeon (Dean, 1975).

- Fur-bearer

Wildlife provided the resource base for the initial economic development of Canada. The expansion of European settlement during the 18th and 19th centuries, precipitated in part by the demand of furs, has had a large impact of determining the course of exploration and development of the country (Foster, 1978). As a result of overtrapping and agricultural expansion in the west,

Table 11

Number issued and revenue from hunting licences, by province or territory of sale, 1975 - 1976

Type of licence issued and province of issue	Number of licences issued 1975 - 1976 (thousands)	Revenue 1975 - 1976 (thousands of dollars)
Provincial and Territorial Game Licences*		
Newfoundland	78	399
Prince Edward Island	6	14
Nova Scotia	112	660
New Brunswick	109	541
Quebec	423	3 022
Ontario	596	5 043
Manitoba	60	433
Saskatchewan	145	1 259
Alberta	213	1 620
British Columbia	363	3 212
Yukon Territory	5	166
North West Territories	-	-
CANADA	2 110	16 369
Federal Migratory Game Bird Hunting Permits**		
Newfoundland	30,1	105
Prince Edward Island	4,9	17
Nova Scotia	14,0	50
New Brunswick	12,9	45
Quebec	63,8	223
Ontario	148,7	520
Manitoba	42,9	150
Saskatchewan	57,8	202
Alberta	69,2	242
British Columbia	25,9	91
Yukon Territory	0,5	2
North West Territories	0,7	3
CANADA	471,4	1 650

* Includes licences to hunt big and small game species.

** Includes licences to hunt ducks, geese and where seasons are open, snipes, woodcock, pigeons, doves and cranes.

Source: Simpson-Lewis _et al._ (1979).

available habitat and population of species such as beavers declined and continued to fluctuate at low levels through the early 20th century. Concepts of controlled seasons, quotas, registered traplines or fur block systems, careful species introduction, and allocation of reserves have contributed to the stabilization of the industry. In 1975, the value of raw fur production was 53,9$ million. Of this, 66% (35,6$ million) was contributed by wild trapped pelts and the remaining one-third by ranch-raised pelts (mink).

Facing the numerous species of wildlife potentially harvestable by hunters, fishermen and trappers, species are selected according to federal and provincial statistics. Thus, some species like crow, woodchuck (marmot) will be excluded because they are not listed in provincial or federal statistics as a hunted or trapped species.

- Angling and commercial fish

Of the total land and water area (9 974 thousands km^2) 6,2% are occupied by water bodies (Table 1). In fact these lakes and rivers constitute one of the greatest fresh water reserve of the world. Number of species of fish inhabiting these waters are relatively low in number. Canadian freshwater fish total 24 families and 181 species (including exotic and introduced species). Compared to the state of Ohio, in which there are approximately 170 species, this is relatively poor. However, from a fisherman's point of view, quality replaces quantity. The canadian species of Salmon, Trout and Char are unsurpassable (Scott and Crossman, 1974).

One Canadian out of four has fished in 1975 and one fisherman out of six was a visitor thus totaling 5,4 million of Canadians to which are added more than one million visitors from other countries. In 1975, close to 75 million days have been registered (sports fishing). More than half of this time has been spent between July and September. More than 225 million fish were captured and over 1 billion dollars have been spent in relation with this activity. Sports fishing thus represents an economical asset for Canada (Pêches et Environnement Canada, 1978).

4.1.1.3- Pests (wildlife that damages trees)

Generally speaking, pests of natural forests are damage-causing insects. As a matter of fact, the «Forest Pest Management Institute» located in Sault Ste-Marie, Ontario, is a national institute dealing with the management of forest insect pests. National Forest Research Centres are annually surveying insect, disease and other natural (wind damage, dwarf mistletoe, frost, ...) or human agents. Damages by wildlife are locally listed as being part of important forest disease. A review of 1976 forest insect and disease survey annual report (Canadian Forestry Service, 1978) demonstrates the weak and local importance of the problem. Animal damage has only been listed in the Pacific Region where Porcupine feeding killed about 10% of the 25-year-old western hemlock on 800 ha along Khutzeymateen Inlet from McGregor Point to Larch Creek in the Prince Rupert Forest District. Between Terrace and Cedarvale, lodgepole pine were affected in several scattered pockets of 25 to 200 trees. In the Nelson Forest District, porcupines girdled the tops of several western larch near Paulson east of Christina Lake.

As there has been no systematic survey and evaluation of animal damage, selection of species has been done using personnal communications gathered from each province and reference book such as Banfield (1974) which gives the economical interest and potential damage. In western United States, it is estimated that from 8% (Weyer-haeuser lands) to 61% (National Forest Plantation in California) of plantations are affected by animal activity. Most of the damages are of a minor importance and only small portions are sufficiently devastated to measure the economical loss (Harestad, 1978).

4.1.2- Atlantic provinces

4.1.2.1- Rare, threatened and endangered species

The Atlantic provinces contain 28 species of wildlife which are considered rare, threatened or endangered (Table 12).

- Arctic shrew and Gaspé shrew are rare species in Nova Scotia. The use of wet river - flood plain meadows and of fields on diked saltmarsh meadows for anything other than hay or pasturage would affect local populations and could eliminate them entirely (Gilhen and Scott, 1981).

- The Newfoundland race of the American marten is rare on the Island of Newfoundland. The primitive range was generally throughout the forested regions of the province. Authorities agree that marten are animals of mature coniferous or mixed wood forest. The decline has been the result of human influences: excessive trapping and timber harvesting. A the present time, the remaining population inhabits the boreal forest around Little Grand Lake and Gamble Lake (Novakowski, 1970). According to Rowe (1972), this is one of the more productive boreal forest section in Newfoundland. No estimates of the present day population exists. However, it is generally accepted that marten was never a plentiful species in the Province. Wood exploitation must result in the loss of an essential requirement for denning or food acquisition especially where clearcutting is practised. The marten population in Newfoundland is not endangered at the present time, but it must be considered threatened by increasing logging activity (Skinner, COSEWIC, 1979). Status assigned to the species by COSEWIC: Not in any category.

- Eastern cougar, formerly distributed all across North America, is now considered as being endangered by COSEWIC. Mainly encountered in coniferous and mixed forests of New Brunswick and Nova Scotia, the most important factor affecting the distribution and abundance is the density of prey (deer) (Van Zyll de Jong and van Ingen, COSEWIC, 1978).

Table 12

Atlantic provinces - Rare, threatened and endangered species

Species	New Brunswick	Nova Scotia	Prince Edward Island	Newfoundland	Status	Author
Arctic shrew		X			Peripheral	(Gilhen and Scott, 1981)
Gaspé shrew		X			Rare - peripheral	(Gilhen and Scott, 1981)
American marten				X	Endangered-undetermined	(Novakowski, 1970; Cosewic, 1979)
Eastern cougar	X	X			Endangered	(Novakowski, 1970, Cosewic, 1979)
Common Loon	X	X	X	X	Threatened	(Stewart, 1974)
Double-cre sted Cormorant	X	X	X	X	Undetermined	(Cosewic, 1978)
Red-shouldered Hawk	X	X			Threatened	(Goodwin, 1977)
Bald Eagle	X	X	X	X	Threatened	(Stewart, 1974)
Osprey	X	X	X	X	Undetermined	(Stewart, 1974)
Peregrine Falcon (anatum)		X	X		Endangered	(Cosewic, 1978)
Piping Plover	X	X	X	X	Threatened	(Cosewic, 1979)
Long-eared Owl	X	X	X		Rare	(Goodwin, 1977)
Short-eared Owl	X	X	X	X	Rare	(Goodwin, 1977)
Four-toed Salamander		X			Rare	(Leclerc, pers. comm.)
Northern Dusky Salamander	X				Undetermined	(Cook, 1977)
Eastern Grey Treefrog	X				Peripheral	(Cook, 1977)
Blanding's Turtle		X			Endangered	(Stewart, 1974)
Eastern Ribbon Snake		X			Rare	(Cook, 1974)
Northern Ring-necked Snake		X			Rare	(Leclerc, pers. comm.)
Shortnose sturgeon	X				Rare - endangered	(Deacan et al., McAllister and Gruchy, 1977)
Blueback herring	X	X			Rare	(McAllister and Gruchy, 1977).
Atlantic whitefish		X			Endangered	(Deacan et al., 1979)

- The Common Loon was formerly largely distributed across Canada. Illegal hunting, tourist development, and the use of DDT seems to have significantly reduced its population. It is today confined to remote lakes (Stewart, 1974). The Double-crested Cormorant was also a widely distributed species. There are 66 colonies on the east coast which supports approximatively 9 900 nests. Nesting occurs mainly on coastal cliffs and inaccessible islands of the interior (Markham, COSEWIC, 1978). Status assigned by COSEWIC: Not in any category.

- Carnivorous birds, which occupy the summit of trophic level, can be treated as rare species: Red-shouldered Hawk, Long-eared Owl and Short-eared Owl (Goodwin, 1977). Some other carnivorous species have been affected by excessive use of pesticides such as DDT. In Eastern North America, the population of the Bald Eagle and Osprey has considerably declined in the past decades (Godfrey, 1970).

- Peregrine Falcon (anatum) is considered as rare or extirpated in the south-eastern part of the country. This species has a very weak tolerance to any modifications of its habitat; eggs collection for falconery purposes, destruction of nesting sites, utilisation of DDT and the simple presence of humans might have contributed to its decline (Martin, COSEWIC, 1978). Status assigned by COSEWIC: Endangered.

- In Atlantic provinces, the Piping Plover is found and breeds exclusively on the beaches of the seashore and of island lakes and sloughs. The classically described habitat consists of sandy beaches. Any human activity could represent a threat for this species (Bell, COSEWIC, 1978). Status assigned to the species by COSEWIC: Threatened.

Many species of amphibians and reptiles are rare and isolated in these provinces. The Gray Treefrog in the valley of the St-John River, the Ribbon Snake in southwestern Nova Scotia and Pickerel

Frog (Cook, 1977). The Four Toed Salamander and the Northern Ring-necked Snake are rare species in the Atlantic provinces (Leclair, 1980). The disjunct Blanding's Turtle population of Nova Scotia is partly protected by the Kejimkujik National Park.

Three species of fish are rare and endangered. The Shortnose Sturgeon which is found in the St-John River; this species is endangered in United Stated (McAllister and Gruchy, 1977). The Blueback Herring is limited to Shubenacadie, Stewiake, St-John Rivers and the Bras d'Or lake of Cape-Breton Island (McAllister and Gruchy, 1977). Finally the Atlantic Whitefish is an endangered species in Canada. It is protected in Nova Scotia (McAllister and Gruchy, 1977).

4.1.2.2- Recreational and commercial species

Atlantic provinces represent a 539 103 km^2 composites of coniferous mixed hardwood and tundra natural vegetation associations providing habitat to a variety of ungulate furbearers and bird species. Inland lakes, coastal features and offshore islands attract millions of seabirds and shorebirds. More than 120 000 km^2 have been classified as lands with high capability for use by ungulates. Extensive, and in some places, deeply-indented coastlines are characterized by tidal lagoons, mud flats and salt water marshes, and attract thousand of waterfowl to the Atlantic Provinces during annual migrations. In total, 761 351 ha of high-capability habitat for waterfowl have been classified as essential in Nova Scotia, New Brunswick and Prince Edward Island (Simpson-Lewis et al., 1979).

Of a total area of 51 800 km^2 Nova Scotia comprises 3 000 lakes (Cumming, 1980). In New Brunswick there are 1 170 lakes (4 ha and over) of which 70% of the total area is located in the southwestern part of the province (Hooper, undated).

Game species represent an asset for the economy of the Atlantic provinces. For example, sports fishing in Nova Scotia (interior coastal) has generated activities for a global amount of $14,2 million in 1974 (Cumming, 1980). In this same province fur trade has paid over $1,6 million to trappers in 1979-1980 (van Nostrand, 1980).

Although we have listed all species having an economical asset (Table 13), some species are however more exploited than other. Results from a survey of sports fishing in Nova Scotia indicated that 20% of anglers are preferring brook trout, 15% rainbow trout, 12% Atlantic salmon, 8% lake trout and 6% ouananiche. These numbers are showing the high preference (60%) of anglers for the Salmonidae family. Other choices are hot water and salt water species (Cumming, 1980).

4.1.2.3- Potential pests

Table 14 presents a listing of potential pests for the Atlantic Provinces.

4.1.3- Central Provinces (Quebec and Ontario)

4.1.3.1- Rare, threatened and endangered species

Forty-seven (47) mammals, birds, amphibians, reptiles and fishes have been grouped under this category (Table 15). More than half of these species are amphibians, reptiles and fishes. In fact, most of the reptiles and amphibians encountered in this part of Canada are at the northern limit of distribution especially in the Niagara peninsula of southern Ontario. This area has been excluded of the study because of a low probability of producing forest biomass on a large scale. So species inhabiting specifically this area have not been listed. However, species that could be encountered in the Ottawa region and/or in the St. Lawrence valley have been retained. For example the Shortnose cisco, considered as a threatened species (McAllister and Gruchy, 1977) which lives in the waters of the Great Lakes (Ontario, Superior and probably Huron) have not been listed. At the opposite, the Spotted Turtle, which inhabits the marsh lands of the Huron and Erie lakes, is

Table 13

Atlantic provinces - Recreational and commercial species

Species	Province				Status
	New Brunswick	Nova Scotia	Prince Edward Island	Newfoundland	
Snowshoe hare	X	X	X	X	Small game
Arctic hare				X	Small game
Red squirrel	X	X	X	X	Fur bearer
Beaver	X	X	X	X	Fur bearer
Muskrat	X	X	X	X	Fur bearer
Porcupine	X				Small game
Coyote	X	X			Small game, fur bearer
Red fox	X	X	X	X	Fur bearer
American black bear	X	X	X	X	Big game
Raccoon	X	X	X		Fur bearer
American marten	X				Fur bearer
Fisher	X	X			Fur bearer
Ermine	X	X	X	X	Fur bearer
Long-tailed weasel	X				Fur bearer
American mink	X	X	X	X	Fur bearer
River otter	X	X	X	X	Fur bearer
Lynx	X	X			Fur bearer
Bobcat	X	X	X		Fur bearer
Caribou				X	Big game
White-tailed deer	X	X			Big game
Moose	X	X		X	Big game
Canada Goose	X	X	X	X	Waterfowl
Mallard	X		X		Waterfowl
Gadwall	X	X	X	X	Waterfowl
Pintail	X	X	X	X	Waterfowl
Green-winged Teal	X	X	X	X	Waterfowl
Blue-winged Teal			X	X	Waterfowl
American Widgeon			X		Waterfowl
Shoveler	X	X	X		Waterfowl
Wood Duck	X	X	X	X	Waterfowl
Greater Scamp				X	Waterfowl
Common Goldeneye	X	X	X	X	Waterfowl
Hooded Merganser	X		X		Waterfowl
Common Merganser	X	X	X	X	Waterfowl
Red-breasted Merganser	X	X	X	X	Waterfowl
Spruce Grouse	X				Small game
Ruffed Grouse	X	X	X		Small game
Ringed-necked Pheasant	X	X	X		Small game
Gray Partridge	X	X	X		Small game
American Woodcock	X	X	X		Small game
Common Snipe	X	X	X	X	Small game
Atlantic sturgeon	X	X	X	X	Angling and/or commercial
Blueback herring		X			-
Alewife	X	X	X	X	-
American shad	X	X	X	X	-
Coho salmon		X			-
Rainbow trout	X	X	X		-
Atlantic salmon	X	X	X	X	-
Brown trout	X	X		X	-
Arctic char	X			X	-
Brook trout	X	X	X	X	-
Lake trout	X	X			-
Lake whitefish	X	X		X	-
Round whitefish	X				-
Atlantic whitefish		X			-
Rainbow smelt	X	X	X	X	Angling and/or commercial
Chain pickerel	X	X			-
Brown bullhead	X	X			-
American eel	X	X	X	X	-
Burbot	X				-
Atlantic tamcod	X	X			-
White perch	X	X	X		-
Striped bass	X	X	X		-
Red breast sunfish	X				-
Pumkinseed	X				-
Small mouth bass	X	X			-
Yellow perch	X	X			-

Table 14

Potential pests - wildlife known to damage trees

Species	Province			
	New Brunswick	Nova Scotia	Prince Edward Island	Newfoundland
Snowshoe hare	X	X	X	X
Eastern Chipmunk	X			
Red squirrel	X	X	X	X
Beaver	X	X	X	X
Deer mouse	X	X	X	
White-footed mouse	X	X		
Gapper's red-backed vole	X	X	X	X
Meadow vole	X	X	X	X
Porcupine	X	X		
American black bear	X	X		
White-tailed deer	X	X		
Moose	X	X	X	X
Yellow-bellied sapsucker	X	X	X	X

Table 15. Central provinces - Rare, threatened and endangered species

Species	Province		Status	Author
	Que.	Ont.		
Fox squirrel		x	N.I.A.C.	COSEWIC, 1981
Grey fox	x	x	Rare - disjunct	COSEWIC, 1981 - NOVAKOWSKI, 1970
Wolverine	x	x	Rare - to study	COSEMEQ, 1981
American badger		x	N.I.A.C.	COSEWIC, 1979
Eastern cougar	x	x	Endangered - to study	COSEWIC, 1981 - COSEMEQ, 1981
Common Loon	x	x	Undetermined	Stewart, 1974
Double-crested Cormorant	x	x	N.I.A.C.	COSEWIC, 1981
Red-shouldered Hawk	x	x	Rare	Goodwin, 1976
Golden Eagle	x	x	Rare	Goodwin, 1974
Osprey	x	x	Endangered - to study	COSEWIC, 1981 - COSEMEQ, 1981
Peregrine Falcon anatum	x	x	Endangered - to study	COSEWIC, 1981 - COSEMEQ, 1981
Piping Plover	x	x	Threatened - to study	COSEWIC, 1981 - COSEMEQ, 1981
Caspian Tern	x	x	Rare - to study	COSEWIC, 1981 - COSEMEQ, 1981
Great Gray Owl	x	x	Rare	Goodwin, 1976
Long-eared Owl	x	x	Rare	Goodwin, 1976
Short-eared Owl	x	x	Rare	Goodwin, 1976
Kirtland's Warbler		x	Endangered	COSEWIC, 1981
Jefferson's Salamander		x	Rare	Cook, 1976
Silvery Salamander		x	Rare	Cook, 1976
Four-toed Salamander	x		Rare	Leclerc, pers. comm.
Northern Spring Salamander	x	x	Undetermined	Cook, 1976
Pickerel Frog	x		Rare - disjunct	Cook, 1976
Spotted Turtle	x	x	Rare - to study	Stewart, 1976 - COSEMEQ, 1981
Wood Turtle	x		To study	COSEMEQ, 1981
Blanding's Turtle		x	Endangered - disjunct	Stewart, 1974
Eastern Spiny Soft-Shelled Turtle	x	x	Rare - disjunct	Stewart, 1974 - Cook, 1976
Eastern Box Turtle		x	Undetermined	Cook, 1976
Eastern Smooth Green Snake	x	x	To study	COSEMEQ, 1976
Northern Water Snake	x	x	Threatened	Gregory, 1976
Eastern Fox Snake		x	Threatened	Gregory, 1976
Northern Ring-Necked Snake	x		Rare - to study	Leclerc, pers. comm.-COSEMEQ 1981
Black Rat Snake		x	Rare - threatened	Stewart, 1974 - Cook, 1976
Eastern Milk Snake	x	x	Undetermined	Gregory, 1976
Eastern Massasauga		x	Threatened - Endangered	Cook, 1976 - Stewart, 1974
Aurora brook trout		x	Undetermined	McAllister and Gruchy, 1977
Opeongo lake whitefish		x	Rare	McAllister and Gruchy, 1977
Redside dace		x	Threatened	McAllister and Gruchy, 1977
Cultips minnow		x	Rare	McAllister and Gruchy, 1977
Cooper redhorse	x		Endangered	McAllister and Gruchy, 1977
River redhorse	x		Rare	McAllister and Gruchy, 1977
Brindled madtom catfish		x	Rare	McAllister and Gruchy, 1977
Striped bass	x		Endangered - to study	Labrecque, 1981 - COSEMEQ, 1981
Long eared sunfish	x		Endangered - to study	Gruchy *et al.*, 1979-COSEMEQ, 1981
Channel darter	x		To study	COSEMEQ, 1981

also encountered as disjunct populations in Eastern Ontario and southern Quebec. This species is listed as being endangered (Stewart, 1974).

The Fox squirrel was introduced around 1890 on Pelee Island where it is still firmly established. Since 1972, three specimens have been recovered in southern Manitoba which suggests a recent range expansion (Shoesmith and Wrigley, COSEWIC, 1978). Status given by COSEWIC: not in any category.

The Grey fox is found only at the southern limit of Ontario and Quebec. Little is known of its habitat requirements which are mainly found in hardwood forests. Climate and agricultural development could affect the Grey fox. It is considered as rare by COSEWIC (1981) and peripheral by Novakowski (1970).

Naturally rare in Quebec, Wolverine has not been observed or recorded by trappers since a few years now (COSEMEQ, 1981). The American badger is rare in south-western Ontario and absent in Quebec. The major limiting factors are habitat losses and increasing intensive agricultural practices (Stardom, COSEWIC, 1978).

The Eastern cougar is also present in central provinces. It is protected by law in Ontario, but not in Quebec (COSEMEQ, 1981). Same limiting factors as in Atlantic Provinces are noted by authors: density of prey and human populations (COSEWIC, Van Zyll de Jong, Van Ingen, COSEWIC, 1978).

Some carnivorous birds, widely but thinly distributed, are also grouped under this category. The Common Loon, present on the wild lakes of these provinces has an indeterminate status. It might have been affected by pesticides, summer cottage development and the outboard motor activity (Stewart, 1974). Raptors populations have also been negatively harmed by DDT: Osprey, Golden Eagle, Red-shouldered Hawk. Other raptors, the Long-eared Owl, the

Short-eared Owl (Goodwin, 1977) and the Great Gray Owl are naturally rare since they occupy the top of food chains and consequently require large areas to survive. The Great Gray Owl is particularly sensitive to habitat modifications such as land clearing and logging activities in the Boreal Forest Region.

The Double-crested Cormorant nests on the eastern coast of Quebec and in the Great Lakes area in Ontario. The loss of nesting habitats and man's disturbance are the main limiting factors (Markham, COSEWIC, 1978).

The Peregrine Falcon (Anatum) has been likely extirpated from the Central Provinces as well from the Atlantic Provinces. Persistant organochlorine compounds, used as agricultural pesticides, are the major causative agents in the decline of the Peregrine Falcon in many parts of the world (Martin, COSEWIC, 1978).

Two species related to aquatic habitats have also been retained. The Piping Plover nests on the beaches of the Great Lakes region and in the Gulf of the St. Lawrence River. The decline of the species is due mainly to human activity on the beaches (Bell, COSEWIC, 1978). The Caspian Tern is mainly encountered on small islands, far from the mainland, with little or no vegetation. They are sensitive to changes in water level and to pollution of the waters that they hunt in (Martin, COSEWIC, 1978).

The Kirtland's Warbler is one of the world's most critically endangered birds. In 1977, a singing male was found near Petawawa, Ontario. In 1978, the same bird was relocated near Petawawa and another was found in Quebec. The world population has been estimated to be 400. Habitat loss and cowbird parasitism are two known factors which have reduced the size of the population. Formerly, the extensive fires in the pinelands created new breeding habitat as the older, less suitable jack pine was burned and the seed was released to regenerate the area to pine growth. In modern times, forest fire control has reduced the total acreage and size of individual burns and forest management practices encourage the conversion of jack pine to red pine or hardwoods (Chamberlain, COSEWIC, 1978).

The Canadian herpetofauna differs from birds and mammals by the peripheral distribution and disjunct populations of many species. Status is more difficult to assign. Two rare species are related to eastern hardwood forests: the Jefferson Salamander and the Silvery Salamander (Cook, 1977). One species, the Fourtoed Salamander, frequently associated with the Sugar maple - Yellow birch forest type (Neill, 1963), is rare in Quebec (Leclair, 1980). The Northern Spring Salamander is known from at least a half a dozen localities in southern Quebec's Eastern Townships (Cook, 1977). Change in habitat through land-clearing might have caused the decline of the Pickerel Frog in southern Ontario and Quebec (Cook, 1977). The Spotted Turtle is present in very low numbers in the St. Lawrence River valley and in the Sherbrooke area (COSEMEQ, 1981). The Blanding Turtle and the Eastern Spiny Softshell Turtle, considered as rare or endangered (Stewart, 1974), are encountered in Quebec and Ontario. The Wood Turtle exists in very low numbers in restricted habitats in southern Quebec. Its status should be specified (COSEMEQ, 1981). The Eastern Box Turtle has recently appeared on Pelee Island in south-western Ontario. The Water Snake is a threatened species (habitat loss and specific food availability) (Gregory, 1977). The Fox Snake is also threatened (Gregory, 1977). The Ring-necked Snake, the Eastern Milk Snake and the Eastern Smooth Green Snake occupy very restricted habitats and their distribution is generally unknown. Status should be specified (COSEMEQ, 1981). The Black Rat Snake is one of the rare venemous snakes in Canada also encountered in southern Ontario. Reptiles and amphibians, generally inhabiting southern Quebec and Ontario, are highly influenced by urban and industrial development, land drainage and clearing, man's harassment and habitat disturbance.

Ten species of fishes are rare or endangered. Most of these are living in the Great Lakes and the St. Lawrence River. This is the case of the Redside dace, found only in gravel or stony bottomed of clear streams flowing into western Lake Ontario, is sensitive to turbidity and silting (McAllister and Gruchy, 1977). The Cutlips minnow is a rare species confined to warm, clear, gravelly streams of the St. Lawrence River and its tributaries and on the north shore of Lake Ontario, also in the Lake Champlain. The Copper redhorse is threatened by pollution in the Montreal area and the River redhorse is also a rare species in the same hydrographic systems. The Brindled Madtom catfish is a rare species of the Sydenham River of Ontario (McAllister and Gruchy, 1977).

The Aurora brook trout, which was formerly found in the Temiskaming county (White Pine Lake) in Ontario, has been decimated and it is doubtful that aurora trout lives in any of the lakes from which it was described (McAllister and Gruchy, 1977). The Opeongo lake whitefish is a rare species known from lake Opeongo, Algonquin Park, Ontario (McAllister and Gruchy, 1977). The Stripped bass seems to be endangered or extirpated from Quebec. The last specimen was noted in 1964 (COSEMEQ, 1981). The Long-eared sunfish is probably endangered in Quebec (COSEMEQ, 1981). The status of the Channel darter is unknown in Quebec, elsewhere Gruchy et al. (1979) have classified this species as rare and threatened (COSEMEQ, 1981).

4.1.3.2- Recreational and commercial species

In Quebec, three species of ungulates are present: Moose, Caribou and White-tailed deer. Of the 260 522 km^2 of lands classified in Quebec, more than 180 000 are considered to be high-capability lands for these species. The shorelines of the Ottawa River, the St. Lawrence River, Lac St-Jean, and Iles-de-la-Madeleine provide the prime waterfowl capability areas in Quebec. Of the 702 430 ha of high-capability waterfowl habitat, approximately 90% are designated as class 1 which supports waterfowl during their spring and fall migrations (Simpson-Lewis et al., 1979).

In Ontario, although more than 70 000 km² of high-capability class 2 and 3 ungulate lands have been classified, no essential class 1 wintering grounds have been identified. The variety of wetlands surrounding the Great Lakes, the St. Clair marshes, the Ottawa and St. Lawrence River valleys, the Trent-Severn River, and the isolated fertile marshlands within the northern portions of the province near Lake of the Woods, Thunder bay, and Lake Abitibi, combine to provide 11 765 km² of class 1 habitat for waterfowl (Simpson-Lewis et al., 1979).

The use of fauna for recreation in Quebec only totals 18 million days. More than 77 000 metric tons of fish are captured annually in Quebec. Of this number, more than 13 000 tons come from recreational activities (Pike, 32%; Trout and Char, 27%; Sauger, 18%,...). Terrestrial fauna and waterfowl furnish 7 500 metric tons of eadible meat coming from the harvest of more than 4,6 million animals. Moose is the most popular species for big game hunting. Migratory birds and waterfowl hunting is highly appreciated by hunters of Quebec. Furbearers trapped by native people and others represent a total value of 17,7 million dollars in 1977 - 1978 (Pelletier et al., 1981).

In 1975, the canadian value of raw fur production was 53,9 million dollars. Of this total, 31% was produced in Ontario (Simpson-Lewis et al., 1979). Half the number of beaver trapped in Canada were in northern Ontario. For the same year, more than 600 000 provincial and 139 000 federal hunting permits have been delivered. There are approximately 75 000 moose hunters in Ontario and for the 1979 - 1980 year, 10 000 animals were killed.

Game species thus represent a prime recreative and commercial value. Table 16 enumerates selected species.

4.1.3.3- Potential pests

Sixteen species have been selected as potential pests (Table 17). Reported damages are locally important. In 1978, the Meadow vole

Table 16. Central provinces - Recreational and commercial species.

Species	Provinces Que.	Ont.	Status
Eastern cottontail	x	x	Small game
Snowshoe hare	x	x	Small game
Gray squirrel	x	x	Fur bearer
Red squirrel	x	x	Fur bearer
Beaver	x	x	Fur bearer
Muskrat	x	x	Fur bearer
Coyote	x	x	Small game - fur bearer
Wolf	x	x	Small game - fur bearer
Red fox	x	x	Fur bearer
American black bear	x	x	Big game - fur bearer
Raccoon	x	x	Fur bearer
American marten	x	x	Fur bearer
Fisher	x	x	Fur bearer
Ermine	x	x	Fur bearer
Long-tailed weasel	x	x	Fur bearer
American mink	x	x	Fur bearer
River otter	x	x	Fur bearer
Lynx	x	x	Fur bearer
Bobcat	x	x	Fur bearer
Caribou	x	x	Big game
White-tailed deer	x	x	Big game
Moose	x	x	Big game
Canada Goose	x	x	Waterfowl
Mallard	x	x	Waterfowl
Black Duck	x	x	Waterfowl
Pintail	x	x	Waterfowl
Green-winged Teal	x	x	Waterfowl
Blue-winged Teal	x	x	Waterfowl
American Widgeon	x	x	Waterfowl
Wood Duck	x	x	Waterfowl
Red Head	x	x	Waterfowl
Ring-necked Duck	x	x	Waterfowl
Lesser Scaup	x	x	Waterfowl
Greater Scaup	x	x	Waterfowl
Common Goldeneye	x	x	Waterfowl
Bufflehead	x	x	Waterfowl
Ruddy Duck	x	x	Waterfowl
Hooded Merganser	x	x	Waterfowl
Common Merganser	x	x	Waterfowl
Red-breasted Merganser	x	x	Waterfowl
Spruce Grouse	x	x	Small game
Ruffed Grouse	x	x	Small game
Willow Ptarmigan	x		Small game
Sharp-tailed Grouse	x	x	Small game
Bobwhite		x	Small game
Ring-necked Pheasant	x	x	Small game

Species	Provinces Que.	Ont.	Status
Gray Partridge	x	x	Small game
Rails	x	x	Small game
Common Gallinule	x	x	Small game
American Coot	x	x	Small game
American Woodcock	x	x	Small game
Common Snipe	x	x	Small game
Lake sturgeon	x	x	Angling and/or commercial
Atlantic sturgeon	x		
Alewife	x		-
American shad		x	-
Pink salmon		x	-
Chinook salmon		x	-
Rainbow trout	x	x	-
Atlantic salmon	x	x	-
Brown trout	x	x	-
Arctic char	x		-
Brook trout	x	x	-
Lake trout	x	x	-
Lake herring	x	x	-
Lake whitefish	x	x	-
Round whitefish	x	x	-
Rainbow smelt	x	x	-
Goldeye	x	x	-
Mooneye	x	x	-
Redfin pickerel	x		-
Grass pickerel	x	x	-
Northern pike	x	x	-
Muskellunge	x		-
Chain pickerel	x	x	-
Brown bullhead	x	x	-
Channel catfish	x	x	-
American eel	x	x	-
Burbot	x		-
Atlantic tomcod		x	-
White perch		x	-
White bass	x	x	-
Pumpkinseed	x	x	-
Bluegill	x	x	-
Smallmouth bass	x	x	-
Largemouth bass	x	x	-
Yellow perch	x	x	-
Sauger	x	x	-
Walleye	x	x	-
Fresh water drum	x	x	-

Table 17. Central provinces - potentiel pests

Species	Provinces	
	Que.	Ont.
Eastern cottontail	x	x
Snowshoe hare	x	x
Eastern chipmunk	x	x
Gray squirrel	x	x
Red squirrel	x	x
Beaver	x	x
Deer mouse	x	x
White-footed mouse	x	x
Gapper's red-backed vole	x	x
Meadow vole	x	x
Porcupine	x	x
American black bear	x	x
White-tailed deer	x	x
Moose	x	x
Yellow-bellied sapsucker	x	x

has caused severe damages in many plantations and ornemental trees in the Quebec City surroundings. In 1979, two plantations of the Gatineau river area have been affected (50 trees were injured). Squirrels are locally affecting jack pine. Porcupines are regularly stripping the bark of trees. In 1980, two cases were reported as moderate in young jack pine stands in Quebec and one plantation has suffered severe damages and 60% of the trees were injured (Lachance and Laflamme, 1980).

4.1.4- Prairie Provinces

4.1.4.1- Rare, threatened and endangered species

Manitoba, Saskatchewan and Alberta contain the most important (70%) agricultural lands of Canada and are known as the granary of the world. The distribution of many wildlife species considered as rare, threatened or endangered is associated to the grassland of the Prairie Provinces. This is the case of the Black-tailed prairie dog, the Pocket gopher, the Kit fox, the Black-footed ferret, the Greater Prairie Chicken, of the Burrowing Owl and many amphibians, reptiles and fishes. As no forest biomass alternatives are foreseen on a large scale in this area (figure 3, see grassland) species inhabiting specifically this area have been excluded. However, species, such as the Fox squirrel, which are also encountered in the Parkland or in the Boreal forest region, will be considered here.

Eight mammals, 21 birds, 3 reptiles and 3 species of fishes have been classified under this category (Table 18).

The Fox squirrel has been recovered in southern Manitoba, which suggests a recent range expansion of this squirrel from North Dakota and Minnesota. Population is unknown in Manitoba (Shoesmith and Wrigley, COSEWIC, 1978). Probably rare and localized habitat is dry woods of oak, aspen and maple (Nero and Wrigley, 1977).

Table 18. Prairie provinces - Rare, threatened and endangered species.

Species	Province Man.	 Sask.	 Alta.	Status	Author
Fox squirrel	x			N.I.A.C.	COSEWIC, 1981
Northern Rocky Mountain wolf			x	Rare	Banfield, 1974
Grey fox	x			Rare	COSEWIC, 1981
Big plains grizzly			x	N.I.A.C. - endangered	COSEWIC, 1981; Novakowski, 1970
Wolverine	x	x	x	Rare	Nero and Wrigley, 1977
Rocky Mountain cougar	x	x	x	Rare	Banfield, 1974; Nero and Wrigley, 1977
Mule deer	x			Rare	Shoesmith, 1977
Wood bison			x	Endangered	COSEWIC, 1981; Novakowski, 1970
Common Loon	x	x	x	Undetermined	Stewart, 1974
Western Grebe	x			Rare	Nero and Wrigley, 1977
White Pelican	x	x	x	Threatened	COSEWIC, 1981
Double-crested Cormorant	x	x	x	N.I.A.C.	COSEWIC, 1981
Trumpeter Swan		x	x	Rare	COSEWIC, 1981
Swainson's Hawk	x	x	x	Rare	Goodwin, 1977
Ferruginous Hawk	x	x	x	Undetermined - rare	Goodwin, 1974; Nero and Wrigley, 1977
Golden Eagle	x	x	x	Rare	Godfrey, 1970; Nero and Wrigley, 1977
Bald Eagle	x	x	x	Rare - endangered	Stewart, 1974; Nero and Wrigley, 1977
Osprey	x	x	x	Undetermined - endangered	Stewart, 1974; Nero and Wrigley, 1977
Prairie Falcon	x	x	x	Undetermined - rare	Godfrey, 1970; Nero and Wrigley, 1977
Peregrine Falcon	x	x	x	Endangered	COSEWIC, 1981; Nero and Wrigley, 1977
Richardson's Pigeon Hawk	x	x	x	Undetermined - endangered	Godfrey, 1970; Nero and Wrigley, 1977
Whooping Crane			x	Endangered	COSEWIC, 1981
Greater Sandhill Crane	x	x	x	N.I.A.C. - rare	COSEWIC, 1981; Nero and Wrigley, 1977
Piping plover	x	x	x	Threatened	COSEWIC, 1981
Caspian tern	x	x	x	Rare	COSEWIC, 1981
Great Gray Owl	x	x	x	Rare	COSEWIC, 1981; Nero and Wrigley, 1977
Long-eared Owl	x	x	x	Rare	Goodwin, 1977
Short-eared Owl	x	x	x	Rare	Goodwin, 1977
Boreal Owl	x	x	x	Rare	Nero and Wrigley, 1977
Plains Hognose Snake	x	x	x	Threatened	Gregory, 1977
Eastern Yellow-Bellied Racer		x		Threatened	Gregory, 1977
Prairie Rattlesnake		x	x	Threatened	Gregory, 1977
Lake sturgeon	x			Rare	Nero and Wrigley, 1977
Arctic char	x			Peripheral	Nero and Wrigley, 1977
Round whitefish	x			Peripheral	Nero and Wrigley, 1977

The Northern Rocky Mountain wolf, extremely rare in southern Alberta, could be a sub-species (Banfield, 1974). The Grey fox is a rare species protected in Manitoba.

The Grizzly bear, formerly distributed in all Prairie Provinces has been extirpated from Manitoba and Saskatchewan. It is presently found in Northern and Western Alberta. Conflict with human activities is the major factor causing declines both through hunting and killing nuisance bears (Macey, COSEWIC, 1979).

The Wolverine is also a rare species of the boreal forest region. Trapping and the reduction of the caribou herds have caused its decline (Nero and Wrigley, 1977). The Mountain lion is found in relatively high numbers in the Rocky Mountains. Only a few individuals inhabit the fluvial valleys and wooden hills of the prairies (Banfield, 1974). Considered as rare, it is protected in Manitoba by the Wildlife Act (Nero and Wrigley, 1977).

During the past 75 years, there has been a reversal of Mule deer population in Manitoba. The original aspen parkland and native prairie areas were converted to farming cereal grains and cattle. With the onset of forest clearing and plowing of the prairies by early settlers, a substantial amount of forest edge habitat favorable to the White-tailed deer was created (Shoesmith, 1976).

The Wood bison, formerly distributed across the prairies and the Parkland, has been decimated by excessive hunting and land clearings. It is only found today in national parks (Nero and Wrigley, 1977).

The Common Loon is also considered as having an undetermined status in the Prairies (Stewart, 1974) and might be endangered (Nero and Wrigley, 1977). In these provinces, the recreative uses of water bodies and the pesticides seems to generate the same negative effects than in the Eastern provinces. The Western

Grebe, rare and protected in Manitoba, is also vulnerable to human disturbance and biocides (Nero and Wrigley, 1977).

The White Pelican is a threatened species (Markham, COSEWIC, 1978). Majority of its actual population is located in the Prairie Provinces. This species has very low tolerance to human presence especially during nesting season. It thus chooses inacessible, untreed islands for this activity. Use of biocides also constitute a potential threat (Nero and Wrigley, 1977). The Double-crested Cormorant occurs together with Pelican in many sites. Local declines have occurred due to the loss of habitats through human disturbances. A prime example is the loss of the island at Lake Newell, due to irrigation development, which supported 40% of Alberta's breeding population (Markham, COSEWIC, 1978). They are equally in need of protection from human disturbances during the breeding season (Nero and Wrigley, 1977).

Scattered flocks of natural breeding populations of Trumpeter Swans persist today in Alberta and Saskatchewan. In Manitoba, where it formerly bred, a few are being reared in captivity (Nero and Wrigley, 1977). The large territory required by each nesting pair serves to limit the number. Many are killed each year during open waterfowl seasons (Mackay, COSEWIC, 1978).

Many species of diurnal and nocturnal raptors are also included. Their status is varying according to provinces and authors. Scarcity of these species comes from the fact that they occupy the top of trophic level (Goodwin, 1977). This position has however contributed to the concentration of chemicals by their metabolic processes and has had a harmful effects mainly on the eggshell thickness. Thin, fragile eggshells has compromised the breeding success of many species. Other raptors that nest on the top of old trees (hardwood and softwood) are sensitive to the logging of mature forests. These are: Swainson's Hawk, Ferruginous Hawk, Golden Eagle, Bald Eagle, Osprey, Prairie Falcon, Peregrine

Falcon, Richardson's Pigeon Hawk, Boreal, Long-eared, Short-eared and Great Gray Owls.

The Whooping crane, formerly widely distributed in North America, is restricted today in the Wood-Buffalo National Park. The low availability of suitable habitats is the main limiting factor. Winter habitats and large feeding areas while migrating are particularly rare (Gollop, COSEWIC, 1978). The Greater Sandhill Crane has an undetermined status in all three Prairie Provinces. In Manitoba, it nests in the extreme southeastern part of the province (Nero and Wrigley, 1977).

The Piping Plover nests in the southern part of Manitoba and Winnipeg Lakes. There are 150 breeding couples in Saskatchewan and 100 in Manitoba. Populations of these latter provinces are less threatened than in the East (Bell, COSEWIC, 1978). The Caspian Tern is also present in these provinces and possesses the same limiting factors than in Eastern Canada (Martin, COSEWIC, 1978).

Three species of snakes occurring in this forest region are threatened. The Western Hognose Snake is part of a group which are rarely abundant locally even under optimum conditions. These species may therefore be very sensitive to detrimental effects (Gregory, 1977). The Eastern Yellow-bellied Racer is basically relict in Canada, populations are probably very small and therefore sensitive to disturbance (Gregory, 1977).

The Western Rattlesnake is in the group of species which are actively destroyed by humans because they are venomous, resemble venomous snakes or are relatively large (Gregory, 1977).

The Lake sturgeon has been significatively reduced in numbers because of overexploitation and dams construction which prevent the fish from reaching their spawning grounds in swift waters (Nero and Wrigley, 1977). The Arctic char is a peripheral species in Manitoba and is restricted to the coastal region of Hudson Bay (Nero and Wrigley, 1977). The Round whitefish is also a peripheral species in lakes and rivers of extreme northern Manitoba (Nero and Wrigley, 1977).

4.1.4.2- Recreational and commercial species

A total of 440 828 km² of high capability ungulate habitat has been identified in the three Prairie Provinces. Moose, White-tailed deer and Mule deer, Elk and Woodland caribou are supported by 82 058 km² of essential habitat. Most of the 7 642 km² of prime wintering habitats lies within the Saskatchewan Plain between the Manitoba - Saskatchewan boundary and the Manitoba escarpment. Pockets of class 1 habitat have been identified within the mixed wood section of the boreal forest. The Manitoba Lowlands, north of the Interlake area in Manitoba, has been designated as high capability lands for ungulates. Much of the Interlake area and the area west of Lake Manitoba offers little high-quality ungulate habitat (Simpson-Lewis et al., 1979).

In Saskatchewan, elk and white-tailed deer are the indicator species in the parkland, while deer, moose and woodland caribou dominate the more northern boreal forest.

In Alberta, of the 454 764 km² included in the Alberta CLI, 8% have been identified as class 1 wintering habitats, 11% as class 2 and more than 20% as class 3. Diversity of landscape supports prime ungulate habitats for pronghorn, mule and white-tailed deer, moose, elk, mountain sheep and moutain goat. Class 1 lands are scattered across the province in a finger-like pattern paralleling the major river valleys draining from the Rocky Mountains (Simpson-Lewis et al., 1979).

The grassland and transition aspen parkland belt covering a southern semi-circle arching from southeastern Alberta to southwestern Manitoba, provides most of the 158 000 km² of high-capability waterfowl production habitat. Essential nesting cover is supported by the unique prairie sloughs, the water-filled potholes dispersed throughout the extensive moraine and till plains. In addition, the northern boreal forest areas particularly in Manitoba, along the banks of the North and South Saskatchewan rivers, and the smaller lakes, are identified as high-capability migration habitats, used as spring and fall stopover sites (Simpson-Lewis et al., 1979).

In Manitoba, the total production of commercial and sports fishing was 16 631 metric tons for a total value of $12 796 450,00 in 1979-1980. 196 409 fishing permits have been delivered for the same year. 108 033 hunting licences have generated a total revenu of 1 million dollars for the same period (Anonymous, 1980).

In Saskatchewan, the sale of hunting permits has given more than 2 million dollars to the province in 1979. More than 72 000 permits have been sold for game birds hunting. More than 700 000 geese and ducks and 300 000 Upland Game Bird have been harvested. 90918 Big Game licences have been delivered and 48 000 animals were killed (40 000 deer, 4 000 moose, pronghorn, bear,...) (Anonymous, 1979).

In Alberta, hunting, fishing and trapping permits have generated a total revenu of approximately 4 million dollars in 1979. Fur trapping has paid 15 million dollars to trappers while commercial fishing totals revenues of 2,8 million dollars.

Table 19 presents a listing of selected species.

4.1.4.3- Potential pests

Table 20 enumerates potential pests of the Prairie Provinces.

Table 19. Prairie provinces - Recreative and commercial species.

Species	Status	Manitoba	Saskatchewan	Alberta
Snowshoe hare	Small game - fur bearer	x		x
White-tailed jackrabbit	Small game	x	x	
Red squirrel	Fur bearer	x	x	x
Beaver	Fur bearer	x	x	x
Muskrat	Fur bearer	x	x	x
Coyote	Fur bearer - small game	x	x	x
Wolf	Fur bearer - small game	x		x
Red fox	Fur bearer	x	x	x
Black bear	Big game - fur bearer	x	x	x
Grizzly bear	Big game			x
Raccoon	Fur bearer	x	x	x
American marten	Fur bearer	x	x	x
Fisher	Fur bearer	x	x	x
Ermine	Fur bearer	x	x	x
Long-tailed weasel	Fur bearer	x	x	x
Least weasel	Fur bearer	x	x	x
Mink	Fur bearer	x	x	x
Wolverine	Fur bearer	x	x	x
American badger	Fur bearer	x	x	x
River otter	Fur bearer	x	x	x
Lynx	Fur bearer	x	x	x
Bobcat	Fur bearer	x	x	x
Woodland caribou	Big game	x	x	x
Mule deer	Big game	x	x	x
White-tailed deer	Big game	x	x	x
Moose	Big game	x	x	x
Elk	Big game	x	x	x
Pronghorn	Big game			x
Cougar	Big game			x
Goat				x
Whistling Swan	Waterfowl	x		
Canada Goose	Waterfowl	x	x	x
Brant Goose	Waterfowl	x	x	x
White-fronted Goose	Waterfowl	x	x	x
Snow Goose	Waterfowl	x	x	x
Ross's Goose	Waterfowl	x	x	x
Mallard	Waterfowl	x	x	x
Black Duck	Waterfowl	x		
Pintail	Waterfowl	x	x	x
Green-winged Teal	Waterfowl	x	x	x
American Widgeon	Waterfowl	x	x	x
Shoveler	Waterfowl	x	x	x
Wood Duck	Waterfowl	x	x	x
Lesser Scaup	Waterfowl	x	x	x
Common Goldeneye	Waterfowl	x	x	x
Burrow's Goldeneye	Waterfowl	x	x	x
Bufflehead	Waterfowl	x	x	x
Harlequin Duck	Waterfowl			x
Ruddy Duck	Waterfowl	x	x	x

Table 19. Prairie provinces - Recreative and commercial species (cont'd).

Species	Status	Manitoba	Saskatchewan	Alberta
Hooded Merganser	Waterfowl	x	x	x
Common Merganser	Waterfowl	x	x	x
Blue Grouse	Game bird			x
Spruce Grouse	Game bird	x	x	x
Ruffed Grouse	Game bird	x	x	x
Sharp-tailed Grouse	Game bird	x	x	x
Ring-necked Pheasant	Game bird	x	x	x
Gray Partridge	Game bird	x	x	x
Sandhill Crane	Game bird	x	x	
Rails	Game bird	x		x
Common Gallinule	Game bird	x		
American Coot	Game bird	x	x	x
Common Snipe	Game bird	x	x	x
American Woodcock	Game bird	x		
Lake sturgeon	Angling or commercial	x	x	x
Kokanee	Angling or commercial			x
Cuthroat	Angling or commercial			x
Rainbow trout	Angling or commercial	x	x	x
Brown trout	Angling or commercial	x	x	x
Brook trout	Angling or commercial	x	x	x
Dolly varden	Angling or commercial			x
Lake trout	Angling or commercial	x	x	x
Lake herring	Angling or commercial	x	x	x
Blackfin cisco	Angling or commercial	x		
Lake whitefish	Angling or commercial	x	x	x
Mountain whitefish	Angling or commercial			x
Arctic grayling	Angling or commercial	x	x	x
Goldeye	Angling or commercial	x	x	x
Mooneye	Angling or commercial	x	x	
Northern pike	Angling or commercial	x	x	x
Muskellunge	Angling or commercial	x		
Bigmouth buffalo	Angling or commercial	x	x	
Brown bullhead	Angling or commercial	x	x	
Channel catfish	Angling or commercial	x		
Burbot	Angling or commercial	x	x	x
White bass	Angling or commercial	x		
Pumpkinseed	Angling or commercial	x		x
Small mouth bass	Angling or commercial	x		
Black crappie	Angling or commercial	x		x
Yellow perch	Angling or commercial	x	x	x
Sauger	Angling or commercial	x	x	x
Walleye	Angling or commercial	x	x	x
Freshwater drum	Angling or commercial	x	x	

Table 20. Prairie provinces - Potential pests.

Species	Manitoba	Provinces Saskatchewan	Alberta
Snowshoe hare	x	x	x
Eastern chipmunk	x		
Gray squirrel	x		
Red squirrel	x	x	x
Beaver	x	x	x
Deermouse	x	x	x
Gapper's red-backed vole	x	x	x
Meadow vole	x	x	x
Porcupine	x	x	x
Black bear	x	x	x
White-tailed deer	x	x	x
Mule deer	x	x	x
Moose	x	x	x
Yellow-bellied sapsucker	x	x	x

4.1.5- British Columbia

4.1.5.1- Rare, threatened and endangered species

Several wildlife species have decreased in range and numbers in British Columbia, a few have disappeared. Pressure resulting from man's increasing impact on the environment continues to jeopardize some species. Elimination of habitat is frequently the most important factor contributing to the decline of a species (Anonymous, B.C. Ministry of Environment, 1979).

In British Columbia, 34 species have been retained as being rare, threatened and endangered (Table 21).

The Vancouver Island marmot habitat is in alpine and subalpine areas characterized by steep slopes, talus debris and open meadows. Such habitats are located on the higher mountains on Vancouver Island. Some of the decline might have been natural due to invasion of trees, but it is likely the bulk of it has been due to man, either through wanton killing or excessive disturbance through development (Munro, COSEWIC, 1978).

The Lilloet and Chelan grizzly are distinct geographical population of Grizzly bear. The former, originally found in southern interior British Columbia, was never abundant and because it was subject to heavy hunting pressure, it is now extremely rare and maybe extinct (Novakowski, 1970). The Chelan grizzly ranged only in western British Columbia on the mainland and is now found in wilderness areas in small isolated population. It has been reduced by hunting pressure and may eventually be protected (Novakowski, 1970).

The American badger is present in a very low density in this province. Loss of habitat and human disturbance could be the main limiting factors (Stardom, COSEWIC, 1978).

Because of continued hunting and poisoning programs numbers of Northern Rocky Mountain cougar (Mountain lion) have been

Table 21. British Columbia - Rare, threatened and endangered species.

Species	Status	Author
Vancouver Island marmot	Endangered	COSEWIC, 1981 - Fish and Wildlife, 1979
Grizzly bear	N.I.A.C. - rare	COSEWIC, 1981 - Novakowski, 1970
American badger	N.I.A.C. - endangered	COSEWIC, 1981 - Fish and Wildlife, 1979
Western mountain lion	Endangered	Novakowski, 1970
Roosevelt american elk	Endangered	Novakowski, 1970
Wood bison	Endangered	COSEWIC, 1981 - Fish and Wildlife, 1979
Common Loon	Undetermined	Stewart, 1974
White Pelican	Endangered	COSEWIC, 1981 - Fish and Wildlife, 1979
Double-crested Cormorant	N.I.A.C.	COSEWIC, 1981
Trumpeter Swan	Rare	COSEWIC, 1981
Swainson's Hawk	Rare	Goodwin, 1977
Bald Eagle	Undetermined	Stewart, 1974
Osprey	Undetermined	Stewart, 1974
Prairie Falcon	Undetermined	Godfrey, 1970
Peregrine Falcon anatum	Endangered - threatened	COSEWIC, 1981 - Fish and Wildlife, 1979
Peregrine Falcon peali	Rare	COSEWIC, 1981
Greater Sandhill Crane	N.I.A.C.	COSEWIC, 1981
Great Gray Owl	Rare	COSEWIC, 1981
Long-eared Owl	Rare	Goodwin, 1977
Short-eared Owl	Rare	Goodwin, 1977
Burrowing Owl	Threatened - endangered	COSEWIC, 1981 - Fish and wildlife, 1979
Pacific Giant Salamander	Undetermined	Stewart, 1974
Olympic-Tailed Frog	Undetermined	Cook, 1976
Northwestern Pond Turtle	Rare	Stewart, 1974
Pacific Rubber Boa	Undetermined	Gregory, 1977
Rocky Mountain Rubber Boa	Undetermined	Gregory, 1977
Pacific Gopher Snake	Threatened	Gregory, 1977
Short-Tailed Snake	Undetermined	Gregory, 1977
Noody longnose dace	Rare	McAllister and Gruchy, 1977
Speckled dace	Rare	McAllister and Gruchy, 1977
Campbell sucker	Rare	McAllister and Gruchy, 1977
Giant stickleback	Rare	COSEWIC,1981-McAllister and Gruchy,1977
Y-Prickle back	Rare	McAllister and Gruchy, 1977
Shorthead sculpin	Endangered	McAllister and Gruchy, 1977

diminishing rapidly and the animal is becoming more and more restricted to the isolated areas of the Rocky Mountain Chain (Novakowski, 1970).

Different sites have been identified for the reintroduction of the Wood bison. For example, the surplus animals of Elk Island National Park in Alberta could be transferred to the Upper Hay River area of British Columbia, to Hog Lake area of northwestern Alberta and the Moostoos Hills areas of Westcentral Saskatchewan (Novakowski, COSEWIC, 1978).

Rare birds, already listed in other provinces are also distributed in British Columbia: the Common Loon, the Bald Eagle, and the Osprey described as being endangered by Stewart (1974). Goodwin (1976) has also considered certain raptors as being rare in Canada: Swainson's Hawk, the Long-eared Owl and the Short-eared Owl.

Only one known nesting colony of White Pelican is encountered at Stum Lake, British Columbia (86 nests) (Markham, COSEWIC, 1978). Human disturbances is also the major limiting factor. The Trumpeter Swan nests in British Columbia. There are also winter habitats widespread along the Pacific coast and limited to a few fast-flowing rivers in the north-central interior. The large territory required by each nesting pair serves to limit the number that can be accomodated on the nesting grounds (Mackay, COSEWIC, 1978). Two sub-species of Peregrine Falcon, Anatum and Pealei, nest in British Columbia. Recent information reports a small breeding population (P.F. Anatum) with confirmed breeding near Hop, interior B.C.. The P.F. Pealei is a maritime species seldom occurring inland and non-migratory. It nests along the coast, mainly on the Queen Charlotte Islands. These sub-species do not have the same status. P.F. Anatum is classified as being endangered while P.F. Pealei is rare (Martin, COSEWIC, 1978).

The Great Gray Owl is also present in B.C.. Land clearing and lumbering have adversely affected this species (Nero, COSEWIC, 1979). The Burrowing Owl is also inhabiting B.C.. It is generally reported that the limiting factor in this province is the lack of nest burrows due to the virtual disappearance of the badger (Wedgewood, COSEWIC, 1978).

The Pacific Giant Salamander is the largest species of salamander in the Western part of North America. This species is limited to the humid coastal regions. None of the factors which limit its numbers has been studied (Stewart, 1974). The Olympic-tailed Frog requires cold streams to survive, its habitat could be greatly reduced by clearcutting (Cook, 1977). The Northwestern Pond Turtle is an extremely rare species which has only been observed twice in this province (Stewart, 1974). The Pacific Rubber Boa, the Sharp-tailed Snake and the Rocky Mountain Rubber Boa are species possibly rare or endangered but information is insufficient to specify their status (Gregory, 1977). The Pacific Gopher Snake is isolated in B.C., it is considered as being threatened (Gregory, 1977).

Some species of fish are rare in B.C.. The Noody longnose dace is only known in the Nooksack river in the southwestern part of the province. In the same area, the Campbell sucker of the Salmon and Little Campbell rivers are also rare. The Giant stickleback is confined to a few lakes on Queen Charlotte Island. The Y-Prickle back is also a rare species, known only from Departure Bay, Baker Pass and Saanich Inlet of southern B.C.. This species does not occur outside Canada. The Shorthead sculpin is endangered and occurs only in the waters of the Flathead river in southeasternmost B.C. (McAllister and Gruchy, 1977).

4.1.5.2- Recreational and commercial species

Elk, mule, white-tailed and black-tailed deer, moose, mountain caribou, mountain sheep and mountain goat are species which find protected food and shelter in the variety of vegetation in the mountains, plateaux, valleys, coastal lowlands and northeastern plains of British Columbia. In total, 30% of the 559 336 km^2 surveyed have been identified as high-capability lands for ungulates. Throughout the Cordillera, summer and winter habitats are found in the river valleys, the bottomlands, and at lower elevations on the mountain slopes.

Less than one per cent of the area has been identified as essential waterfowl habitat (16 450 km^2). Dominated by mountainous terrain and deep fast-flowing rivers, common class limitations include adverse topography, unfavourable climate, excessive water depth and poor marsh edge. The tidal flats and bottomlands of the Fraser Delta support migrating ducks, Canada and Snow Geese, Brant and Whistling Swan. Similarly, the tidal flats of the coastal lowlands of southeastern Vancouver Island and the Gull islands attract many species of ducks and geese (Simpson-Lewis et al., 1979).

Faunal resources of British Columbia are very diversified. There are 280 species of mammals, 460 birds and 73 softwater fishes. Many of these have an economic and recreational value. A direct annual net consumptive value has been estimated at $110 785 000,00. This value was generated from the activities of 390 000 licensed fishermen who expend some 5 million angler-day annually and from 3,4 million recreational days of wildlife related activity, including that of about 150 000 resident hunters. The commercial landed value of salmon for 1977 was $108 700 000,00 representing the efforts of 8 500 commercial fishermen. A further 334 500 saltwater sports fishermen caught an estimated 1 500 000 salmon (B.C. Ministry of Forests, 1980).

British Columbia's abundant freshwater fishery offers the angler an experience as rich and varied as the province's 22 000 lakes, 37 major river systems, countless small tributaries and coastal streams. To the angler, trout are the most important freshwater fish in this province. Of the 5 species of salmon, only three are of interest to freshwater fishermen: Chinook, Coho and Kokanee. Char are also important game fish, particularly in large lakes in the central part of the province. Certain warm water fishes (small and large mouth bass, sunfish and perch) have been introduced to B.C.. They seem to be of little interest to anglers compared to trout, salmon and char. With increasing interest in developing urban angling opportunities, these species are becoming more important (B.C. Ministry of Environment, 1979).

Fur-bearers of British Columbia are likely the same species than in other parts of the country: muskrat, squirrel, ermine, beaver, raccoon. Canada lynx was the most valuable species in 1975 - 1976, although the grizzly, cougar and wolverine are other valuable species. In 1975, 400 000 hunting permits have been delivered including big game and game birds. Hunting of mountain goat and mountain sheep require special permits. Mallard accounts for 50% of migrating birds hunting (Simpson-Lewis et al., 1979). The Fish and Wildlife Branch of the Ministry of Environment for this province aims to maintain and raise actual game populations. Table 22 summarizes for main species the estimated population and the projected harvest (B.C. Ministry of Environment, 1979) while Table 23 enumerates selected species.

4.1.5.3- Potential pests

In the Pacific Northwest, nearly all species of birds and mammals have been implicated in causing some form of damage to forest plantations. Many of these species do very little damage, while other impose substantial economic losses (Table 24). On Vancouver Island and in the coastal mainland regions the animal species of greatest importance to the management of plantations are black-tailed deer, Roosevelt elk, snowshoe hare, white-footed mouse, red and Douglas squirrels, blue grouse, and American beaver. In interior areas and the adjacent northwestern United States additional species are important: black bear, mountain beaver, pocket gopher, porcupine and dusky footed woodrat. Most animal damage to plantations occurs as a result of feeding. This damage consists

Table 22. Estimated population, hunter days and harvest number project of the main game species of British Columbia.

Major species	Estimated population	Hunter days project	Harvest number project
Black bear	35 - 90 000	60 000	4 000
Grizzly bear	6 - 7 000	6 000	200
Coyote	85 000 ± 20%	-	15 000
Wolf	6 000 ± 25%	-	-
Cougar	3 300 ± 20%	3 000	200
Caribou	10 - 20 000	20 000	1 000
Moose	240 000 ± 20%	600 000	30 000
Mule deer	100 000 ± 20%	900 000	60 000
Black-tailed deer	310 000 ± 20%		
White-tailed deer	25 000 ± 20%	18 000	1 500
*Canada Goose	75 000 ± 20%	45 000	20 000
Snow Goose	10 - 25 000	4 000	2 000
White-fronted Goose	100 000		

* Juridiction of geese is shared with the federal government.
Source: B.C. Ministry of Environment (1979).

Table 23. British Columbia - Recreational and commercial species.

Species	Status
Eastern cottontail	Small game
Snowshoe hare	Small game
White-tailed jackrabbit	Small game
American red squirrel	Fur bearer
Beaver	Fur bearer
Muskrat	Fur bearer
Coyote	Small game - fur bearer
Wolf	Small game - fur bearer
Red fox	Fur bearer
American black bear	Big game - fur bearer
Grizzly bear	Big game - fur bearer
Raccoon	Fur bearer
American marten	Fur bearer
Fisher	Fur bearer
Ermine	Fur bearer
Long-tailed weasel	Fur bearer
Least weasel	Fur bearer
American mink	Fur bearer
Wolverine	Fur bearer
Striped skunk	Fur bearer
River otter	Fur bearer
Mountain lion	Small game
Lynx	Fur bearer
Bobcat	Fur bearer
Caribou	Big game
Mule deer	Big game
Black-tailed deer	Big game
White-tailed deer	Big game
Moose	Big game
Canada Goose	Waterfowl
White-fronted Goose	Waterfowl
Mallard	Waterfowl
Gadwall	Waterfowl
Pintail	Waterfowl
Blue-winged Teal	Waterfowl
Cinnamon Teal	Waterfowl
American Widgeon	Waterfowl
Wood Duck	Waterfowl
Red Head	Waterfowl
Canvasback	Waterfowl
Common Goldeneye	Waterfowl
Barrow's Goldeneye	Waterfowl
Bufflehead	Waterfowl
Harlequin Duck	Waterfowl
Hooded Merganser	Waterfowl
Common Merganser	Waterfowl
Blue Grouse	Small game

Table 23. British Columbia - Recreational and commercial species (cont'd).

Species	Status
Spruce Grouse	Small game
Ruffed Grouse	Small game
Sharp-tailed Grouse	Small game
Sage Grouse	Small game
Bobwhite	Small game
California Quail	Small game
Ring-necked Pheasant	Small game
Chukar	Small game
Gray Partridge	Small game
American Coot	Small game
Common Snipe	Small game
Band-tailed Pigeon	Small game
Mourning Dove	Small game
Pacific sturgeon	Angling or commercial
American shad	Angling or commercial
Pink salmon	Angling or commercial
Chum salmon	Angling or commercial
Coho salmon	Angling or commercial
Kokanee	Angling or commercial
Chinook salmon	Angling or commercial
Cuthroat	Angling or commercial
Rainbow trout	Angling or commercial
Brown trout	Angling or commercial
Brook trout	Angling or commercial
Dolly varden	Angling or commercial
Lake trout	Angling or commercial
Lake whitefish	Angling or commercial
Mountain whitefish	Angling or commercial
Arctic grayling	Angling or commercial
Rainbow smelt	Angling or commercial
Goldeye	Angling or commercial
Northern pike	Angling or commercial
Burbot	Angling or commercial
Pumpkinseed	Angling or commercial
Black crappie	Angling or commercial
Smallmouth bass	Angling or commercial
Largemouth bass	Angling or commercial
Yellow perch	Angling or commercial
Walleye	Angling or commercial

Table 24. British Columbia - Potential pests.

Eastern cottontail
Showshoe hare
Mountain beaver
Yellow pine chipmunk
Townsend's chipmunk
American red squirrel
Douglas's squirrel
Beaver
Deer mouse
White-footed mouse
Gapper's red-backed vole

Meadow vole
Porcupine
American black bear
Mule deer
Black-tailed deer
White-tailed deer
Moose
Roosevelt american elk

Blue grouse
Yellow-bellied sapsucker

of seed losses, seedling mortality, suppression of seedling growth, and understocking (Harestad, 1976).

4.2- Wildlife habitat relationship (life form)

Approximatively two hundred wildlife species have been discussed in the previous section. It appeared too much an undertaking to evaluate potential interactions with forest biomass management alternatives on a species basis. In order to simplify the understanding of interactions, selected species maintaining the same habitat relationship for reproduction and feeding have been placed under the same «life form». This concept is adapted from Thomas (1979). It is distinctly different from the usual grouping of species by morphological characteristics. It has the advantage of treating many species at one time and so generates a rough index of a species and life form vulnerability to habitat manipulation (Niemi, 1979). However, subjective judgment must be used for species that are poorly documented.

Selected species have first been divided into four major groups based on preferred habitat for reproduction and feeding (Table 25):

1. Reproduce and feed in mature forest
2. Reproduce and feed in other terrestrial habitat
3. Reproduce in terrestrial or aquatic habitat and feed in terrestrial or aquatic habitat
4. Reproduce and feed in aquatic habitat only.

Habitat means the place where an organism lives, it is its «civic number» (Odum, 1976). The generalized habitats group specific habitats that have shared characteristics. For example, mature softwood forest includes all coniferous forest types (spruce, fir, larch, pine, hemlock,...), while mature hardwood comprises all broadleaved forest types (maple, poplar, aspen, birch, beech, ash,...) that have attained maturity. The American marten, for instance, is encountered in Eastern Canada in wetlands (bogs,

Table 25. Life forms descriptions

Milieu	General habitat	Specific requirements		Example	Life form
		Reproduction	Feeding		
Terrestrial	Mature softwood	On or under the ground	Herbivorous	Spruce Grouse, Blue Grouse	1.1
			Carnivorous	Lynx	1.2
		In trees or bushes (snags or trunks)	Herbivorous	Douglas' squirrel	1.3
			Carnivorous and insectivorous	American marten	1.4
	Mature hardwood	On or under the ground	Herbivorous	Eastern chipmunk	1.5
			Carnivorous	Gray fox	1.6
		In trees or bushes (snags or trunks)	Herbivorous	Gray squirrel	1.7
			Carnivorous	Red-shouldered Hawk	1.8
	Immature forest marginal farmland	On or under the ground	Herbivorous	White-tailed deer Moose	2.1
			Carnivorous	Coyote	2.2
	Meadow fields, Alpine meadows	On or under the ground	Herbivorous	Bison	2.3
			Carnivorous	American badger	2.4
	Various forest types (mature, immature, young forest)	On or under the ground	Herbivorous	Porcupine	2.5
			Carnivorous	American black bear Wolf	2.6
		In trees or bushes (snags or trunks)	Herbivorous		2.7
			Carnivorous	Raccoon	2.8
Terrestrial - aquatic	Riparian or terrestrial near lake, river or water body	On the ground or hut, burrows or cliffs	Herbivorous (insectivorous)	Mallard	3.1
			Carnivorous	Whooping Crane	3.2
		In trees or bushes	Herbivorous (insectivorous also)	Wood Duck	3.3
			Carnivorous	Osprey	3.4
		In water	Carnivorous	Four-toed salamander	3.5
Aquatic	Cold and running water (creek, stream, small river	In water	Planctoniphage (insectivorous, carnivorous)	Brook trout	4.1
	Cold and standing water (lake, large river)	In water	Planctoniphage (insectivorous, carnivorous)	Lake trout	4.2
	Warm water and species with other habitat	In water	Planctoniphage (insectivorous, carnivorous	Northern pike	4.3

fens,...) where there are mature black spruce and eastern cedar. In the Rocky mountains it is encountered in Douglas fir, western Cedar and hemlock forest types (Banfield, 1974). The «general habitat» concept represents the first division of the life form.

The second division is the habitat requirement for reproduction in terrestrial environments. Specific requirements for reproduction are: the birth site for mammals, the nesting sites for birds, the egg-laying and birth sites for reptiles. This requirement is divided in two depending if reproduction is done:

1. On the ground or under the ground
2. In trees or shrubs.

A third requirement for wildlife is feeding. In our classification, species that are directly related to biomass (first order consumer) or indirectly related (second or third order) will be treated separately. In these grouping, primary sources of food will take priority on secondary,... For example the Gray Partridge, as many avian species are feeding on tree buds and fruit, but could also eat insects. It will be classified as herbivorous. Omnivorous species, for their part, will be considered as being carnivorous.

Twenty-four life forms have so been defined. Table 25 enumerates the life forms while Table 26 enumerates species contained in each life form.

The following species have not been classified because of a lack of basic information: Eastern Smouth Green Snake, Northern Ring-necked Snake, Wood Turtle, Pacific Gopher Snake and Sharp-tailed Snake.

4.2.1- Mature forests and other terrestrial habitats (84 species)

Certain species can be easily associated to a particular life form. For example, the Spruce Grouse is nearly always noted in

Table 26. Selected species and their life forms

	General habitat	N° of life form	Species and status*	
MATURE FOREST	SOFTWOOD	1.1	Gapper's red-backed vole (P) Rock vole (T) Woodland Caribou (R)	Blue Grouse (PR) Spruce Grouse (P)
		1.2	Lynx (R) Fisher (R) Grizzly bear (RT)	Pacific Rubber Boa (T) Rocky Mountain Rubber Boa (T)
		1.3	Douglas's squirrel (P) Red squirrel (RP)	
		1.4	American marten (TR) Great Gray Owl (T)	Long-eared Owl (T) Boreal Owl (T) Hawk Owl (T)
	HARDWOOD	1.5	Eastern Chipmunk(P) White-footed mouse (P)	
		1.6	Grey fox (T)	
		1.7	Grey squirrel (PR) Fox squirrel (T)	
		1.8	Red-shouldered Hawk (T) Yellow-bellied sapsucker (P)	
OTHER TERRESTRIAL	IMMATURE FOREST	2.1	Yellow pine chipmunk (P) White-tailed deer (RP) Black-tailed deer (R) Mule deer (RPT) Moose (RP) Elk (R) Roosevelt elk (T)	Ruffed Grouse (R) California Quail (R) Bobwhite (R)
	MARGINAL FARMLAND	2.2	Red fox (R) Coyote (R) Least weasel (R) Long-tailed weasel (R)	Peregrine Falcon (anatum) (T) Peregrine Falcon (pealei) (T) Kirtland's warbler (T)
	MEADOW FIELDS	2.3	Townsend's chipmunk (P) Meadow Vole (P) Eastern cottontail (PR) White-tailed jackrabbit (R) Vancouver Island marmot (T) Wood bison (T) Pronghorn (R) Willow Ptarmigan (R)	White-tailed Ptarmigan (R) Sharp-tailed Grouse (R) Sage Grouse (R) Ring-necked Pheasant (R) Chukar (R) Gray Partridge (R) Mountain goat (R) Rocky mountain bighorn (R)
	ALPINE MEADOWS	2.4	Badger (TR) Wolverine (T) Short-eared Owl (T) Burrowing Owl (T) Golden Eagle (T) Prairie Falcon (T) Swainson's Hawk (T) Ferruginous Hawk (T)	Eastern Short-horned Lizard (T) Western Yellow-bellied Racer (T) Eastern Smooth Green Snake Plains Hognose Snake (T) Eastern Fox Snake (T) Prairie Rattlesnake (T)
	VARIOUS FOREST TYPES (mature, immature and young)	2.5	Deer mouse (P) Snowshoe hare (RP) Porcupine (RP)	
		2.6	American black bear (RP) Ermine (R) Bobcat (R) Eastern cougar (T) Western mountain lion (RT) Striped skunk (R) Wolf (RT)	Eastern Box Turtle (T) Eastern Milk Snake (T) Black Rat Snake (T)
		2.7	-	
		2.8	Raccoon (R) Richardson's pigeon Hawk (T)	

* Status: R : Recreational and/or commercial species
T : Rare, threatened or endangered
P : Potential pest

Table 26. Selected species and their life forms (cont'd)

General habitat		N° of life form	Species and status*	
TERRESTRIAL - AQUATIC (Riparian or terrestrial, near lakes or rivers)		3.1	Mountain beaver (RP) American beaver (RP) Muskrat (R) Brant Goose (R) White-fronted Goose (R) Snow Goose (R) Mallard (R) Black Duck (R) Gadwall (R) Pintail (R) Green-winged Teal (R) Blue-winged Teal (R) Cinnamon Teal (R) American Widgeon (R) Arctic shrew (T) Gaspé shrew (T)	Lesser Scaup (R) Ring-necked Duck (R) Redhead (R) Harlequin Duck (R) Canada Goose (R) American Woodcock (R) Common Snipe (R) Ruddy Duck (R) Trumpeter Swan (T) Piping Plover (T) Shoveler (R) Canvasback (R) Greater Scaup (R)
		3.2	Whooping Crane (T) Sandhill Crane (TR) Rails (R) Common Gallinule (R) American Coot (R) Red-breasted Merganser (R) Common Loon (T) Western Grebe (T) White Pelican (T) Double-crested Cormorant (T) American mink (R)	Eastern Spiny Soft-shelled Turtle (T) Northwestern Pond Turtle (T) Blanding's Turtle (T) Northern Water Snake (T) Wood Turtle Ancient Murrelet (T) Spotted Turtle (T) Eastern Ribbon Snake (T) Eastern Massasauga (T) River Otter (R)
		3.3	Wood Duck (R) Common Goldeneye (R) Barrow's Goldeneye (R) Bufflehead (R)	
		3.4	Bald Eagle (T) Osprey (T) Hooded Merganser (R) Common Merganser (R)	
		3.5	Four-toed Salalamander (T) Silvery Salamander (T) Jefferson's Salamander (T) Pacific Giant Salamander (T) Mink Frog (T) Leopard Frog (T)	Olympic-Tailed Frog (T) Northern Spring Salamander (T) Pickerel Frog (T) Eastern Gray Treefrog (T) Dusky Salamander (T)
AQUATIC	Cold and running water (creek, stream or small rivers)	4.1	Arctic Char (R) Brook trout (R) Shorthead sculpin (T) Coho salmon (R) Rainbow trout (R) Cutthroat (R)	Aurora trout (T) Redside dace (T) Atlantic salmon (R) Dolly varden (R) Rainbow smelt (R)
		4.2	Shortnose sturgeon (T) Lake sturgeon (RT) Pacific sturgeon (R) Blueback herring (RT) Alewife (R) American shad (R) Pink salmon (R) Chum salmon (R) Kokanee (R) Chinook salmon (R) Round whitefish (RT)	Mooneye (R) Inconnu (R) Arctic grayling (R) Eulachon (R) Blackfin cisco (T) Moody longnose dace (T) Lake trout (R) Lake herring (R) Opeongo lake whitefish (R) Atlantic whitefish (R) Mountain whitefish (R)
	Warm water and species with other habitats	4.3	River redhorse (T) Cooper redhorse (T) Brown bullhead (R) Channel catfish (R) American eel (T) Burbot (R) Atlantic tomcod (R) White perch (R) White bass (R) Striped bass (RT) Rock bass (R) Pumpkinseed (R) Bluegill (R) Smallmouth bass (R) Black crappie (R) Yellow perch (R) Sauger (R)	Grass pickerel (R) Muskellunge (R) Chain pickerel (R) Cutlips minnow (T) Redfin pickerel (R) Giant stickleback (T) Channel darter (T) Speckled dace (T) Campbell sucker (T) Y-Prickleback (T) Walleye (R) Atlantic sturgeon (R) Long-eared sunfish (T) Red-breast sunfish (R) Freshwater drum (R) Goldeye (R) Northern pike (R) Largemouth bass (R)

* Status : R : Recreational or commercial species
T : Rare, threatened or endangered
P : Potential pest

coniferous forest and is so included in life form 1. In wintertime, the woodland caribou is feeding on lichens growing on the branches and trunks of old conifers and so belongs to this first life form (1.1). Preferred Blue Grouse habitats vary seasonally. In the springtime, nests are encountered in various habitats (burns, denuded hillside, clearings, forest edges,...). In winter, this species inhabits coniferous forests and becomes mainly arboreal. Therefore, as the well-structured forests are becoming more and more scarce because of extensive logging operations, this latter requirement is more important to the species in this study and this species is classified in the first life form (1.1).

Other species preferring younger forest habitats, meadows, marginal farmlands or having no specific preference are grouped under other terrestrial habitats. Moose, for example, known as a mature softwood user gradually moves into coniferous climax forests to gain immature stands where food is more abundant (Banfield, 1974). Other species are more specific to meadows and cleared lands: bison, badger, fox,.... Some species (wolf, porcupine, raccoon,...) are very versatile and have no preference for a specific habitat. They are grouped under various forest types.

Requirements for reproduction in terrestrial habitats comprise the site where mammals bring forth their young, the nesting site for birds and the egg-laying site for reptiles. Species have been divided in two classes depending if they reproduce on or under the ground and in trees or bushes. The former comprises all species that have no specific requirements (ungulates), that build nests on the ground (grouse) or that dig holes (wolves). The latter includes all species that build nests on live or dead trees, dig cavities in trees or use abandonned nests (raccoon, marten, Red-shouldered Hawk,...).

4.2.2- Terrestrial - aquatic habitats (66 species)

This second type of life form includes all vertebrates that use both terrestrial and aquatic habitats. Amphibians, waterfowl, semi-aquatic mammals are an integral part of these life forms. Amphibians use aquatic habitats for reproduction and riparian or terrestrial habitats for feeding. Waterfowl use aquatic habitats for feeding and riparian or terrestrial habitats for nesting. Nests are usually built on the ground around water (Mallard) or further in the forest (Black Duck). Semi-aquatic mammals are also encountered in these habitats. Muskrat and beaver are typical species. River otter, mink are also associated to these life forms. Certain species, Bald Eagle, Osprey, have been included in these life forms because they use aquatic habitats for feeding.

Aquatic habitats are diversified and include all streams, lakes, rivers, bogs, fens, marshes associated with forest and other terrestrial sites.

Requirements for reproduction of these species are likely the same: birth site for mammals, nesting sites for birds and egg-laying area for reptiles and amphibians. These sites are grouped depending on whether reproduction occurs on the ground (ducks), in huts (beaver), under the ground (otter) or on cliffs (eagles) (life forms 3.1 and 3.2). Species that build nests on trees or shrubs are part of life forms 3.3 and 3.4, while species that reproduce in aquatic habitats are confined to life form 3.5. This latter life form comprises exclusively reptiles and amphibians that reproduce and spend part of their life cycle in aquatic habitats (larval stage). The adult stage is related to riparian or terrestrial habitats.

4.3.3- Aquatic habitats (67 species)

This third group comprises all selected fishes. It has been divided in three life forms depending on their specific requirement for cold and running water (creeks, streams, small rivers), cold and standing water (lakes or large rivers), and warm water bodies. The cold water bodies have been divided in two according to their size. In fact, small rivers and streams are more sensitive to sun-heating after logging operations than lakes and large rivers. Species that are encountered in warm water bodies have been included in the same life form. Furthermore, some species such as the Northern Pike, that tolerate various habitats (Scott and Crossman, 1971) have been included in this life form (4.3).. Finally species that are not biologically and ecologically known have also been listed under this life form.

In this group of life forms, no distinction of food requirement has been made because feeding habits are closely related to the size and the age of species. For example, the Northern Pike becomes carnivorous when it reaches 5 cm in size; when smaller they require plankton and insects for growth (Scott and Crossman, 1974). The Brook Trout is another example. Other species, such as the Alewife, require plankton all their life.

5.- POTENTIAL INTERACTIONS

Objective of this chapter is to relate wildlife of concern to biomass management alternatives in order to identify potential interactions. These interactions will be defined along with information contained in literature. The practices included in the Complete Forest Concept, the Short-Rotation-Intensive-Culture and the Production of Native Species on Short Rotation will be compared to the defined life forms. Results from this analysis will stress our actual knowledge of the interactions. Recommendations will be then elaborated to indicate studies that should be undertaken to prevent negative effects before these practices are implemented on a large scale.

5.1- General method

In this type of study, which involves many parameters at a time, it is desirable to prepare a document that highlights and synthetizes all information. A first effort in this direction has been made with the life form concept. As the available information does not refer to all possible combinations, description of interactions will be either general to a group of life forms or specific to one life form or to one species of a particular life form. This method will also be applied to specify known mitigative measures and recommendations. For each forest biomass management alternative, analysis of interaction goes through three distinct steps:

- Description of management practices
- Description of interactions with defined life forms
- Identification of mitigative measures and recommendations.

Synthesis tables relating life form, activities, effects and mitigative measures are built for each alternative. They permit an organized view of the existing knowledge of interactions.

5.2- The Complete Forest Concept

5.2.1- Management practices

As described previously (3.2.1), forest biomass could be extracted either from logged areas, cull or low-grade stands or treated stands (silviculture). In order to predict interactions of this first alternative with wildlife of concern, practices involved are treated as a whole system, which extends the species/activity through time.

The most ideal situation to work with is the management of an untouched wildland. There, the forester starts from the beginning to extract timber, pulpwood and residues for other uses (ex.: energy conversion). This situation is still possible in the boreal forest where areas of commercial forest remain untouched.

The first step to undertake is the preparation of a plan that brings together the purposes of management with the productive capacity of the forest (Davis, 1954). There are two approaches in the preparation of management plans: forest biomass management plans and integrated resources management plans. The first would be appropriate when biomass production is considered the sole use and the second considers other important uses (recreation, wildlife, water production,...). To be able to specify interactions with wildlife of concern, the typical management plan from which activities would be derived will only consider forest biomass production. Activities involved in the preparation of such a plan are not directly favorable or prejudicial to wildlife. These activities usually comprise:

- Markets, labor and economic situation analysis
- Inventory data
- Growth data
- Definition of silviculture methods
- Evaluation of accessibility
- Elaboration of road system to facilitate access
- Elaboration of cutting plan.

Except for the gathering of specific data which implies a field survey, this first step does not directly influence wildlife. However, it is important to stress the fact that the planners define actions that will be undertaken for many years in a given area. As it will be noted later in the description of interactions, many impacts could be attenuated if planners were aware of wildlife characteristics of the managed forest land.

The first activity, likely to be undertaken for the implementation of a management plan is the road lay-out and construction. Access roads can be of different grades, depending on the intensity of utilization. This usually comprises four to six classes: trunk, primary, secondary, tertiary, summer and winter roads. Table 27 gives an example of forest road standards and standard guidelines of forest roads. The numbers included in this table must not be generalized to all companies in Canada as comparative data indicates a lack of uniformity in road standards (Schultz, 1973). The road construction comprises activities that might interact with wildlife. These will be described in the next section (5.2.2): right-of-way clearing, ditching and surfacing, borrow pits, temporary access roads, culvert installation, trucking and road maintenance.

Biomass extraction represents the second activity of the management plan. It can be undertaken in different ways depending of objectives. In the Boreal Forest Region, mechanized clearcut harvesting is the most common practice because of the uniformity of forests. Mature and overmature softwood stands are first cut for timber and pulpwood utilization. Residues are also extracted for energy conversion. Clearcutting could be done different ways varying in size depending on species and diameter of trees. In Alberta, block size limits (pine types or spruce types) are generally 30 ha for sawlog harvesting and up to 200 ha (averaging 140 ha) for pulpwood operation. These numbers cannot be generalized to all provinces since some provinces regulate the size of clearcut while others have no specific regulations.

Table 27. Suggested uniform road classes and minimum standards.

	Road class				
Item	I	II	III	IV	V
Safe design speed kmph	90	70	55	40	-
Sustained speed - kmph	65	50	30	15	-
Maximum degree of curvature	5	8	13	25	-
Sight distance - m	180	140	90	-	-
Maximum favorable grades - %					
Sustained	6	7	8	10	12
Pitch	8	8	10	12	14
Maximum adverse grade - %					
Sustained	4	4	6	6	12
Pitch	5	6	8	8	14
Right-of-way width - m	40	30	25	20	20
Surface width - m	10	9	6	5	5
Maximum bared width - m	27	26	18	9	9
*Cutslopes - Cotan	1-1/2:1	1-1/2:1	1-1/2:1	1-1/2:1	1-1/2:1
*Fillslopes - Cotan	2:1	2:1	1-1/2:1	1-1/2:1	1-1/2:1
Bridge and culvert strength - tons	150	150	100	100	5
Engineering					
Plan	Detailed design	Detailed design	Rough plot	Traverse only	Traverse only
Profile	Detailed design	On cuts and fills over 1,5 m	On steep grades only	On critical grades only	None
R/W Stakes or flags	Both edges	Both edges	Center only	Center only	Center only
Construction stakes	Cut, fill and centerline complete	Centerline and all cuts and fills over 1,5 m	Only at critical areas	Only at critical areas	None

*Subject to soil erodibility at individual sites. On very sensitive terrain, cuts over 1,5 m should be 2:1, fills over 1,5 m should be 3:1.

Class I (primary) : Permanent main road, available year round.
Class II (secondary) : Permanent branch road, generally available 10 months.
Class III (tertiary) : Lateral access through cut-blocks, 10-year average term, limited access during wet periods.
Class IV (temporary) : Temporary truck road within or between cut-blocks (2-year average life).
Class V (access) : Access road for light vehicles (e.g., roads to lookout towers).

Source: Schultz (1973).

Another important parameter in this particular study is the type of material harvested. It is usually divided in two categories: merchantable material and residues. Merchantable material comprises all trees that meet the standard of utilization for marketing as timber and pulpwood. Standards however vary between provinces. In the Coastal forests of British Columbia, the close utilization standard means the removal of all softwood timber over a 23 cm dbh[1], from a stump not more than 30 cm high to a 15 cm diameter (inside bark). For the interior forests of the same province, close utilization is defined as removing all timber in excess of 18 cm dbh from a stump not more than 30 cm high to a 10 cm diameter (inside bark). In the Prairie provinces and central provinces, close utilization means removing all trees from 30 cm stump height to 9 or 10 cm diameter (inside bark) and from a minimum 9 cm diameter breast height (Reed, 1978). Residues comprise unmerchantable trees or shrubs, tops and branches, dead standing trees (snags), down woody material (logs) and sometimes the stump-root system. Logging methods could also be of some interest in the analysis of interactions. Cutting methods will not be discussed separately, but will be generalized in two categories depending if forest biomass is extracted in one operation (stem and residues) or in two operations (first the stem, then residues). All biomass harvested will then be hauled or carried to the landing for loading on trucks.

In any management plan, reforestation must be seen as a critical step. Without new timber crops developping promptly, sustained yield forestry commitments would be gradually invalidated (Schultz, 1973). In a complete forest concept, this step might appeared more critical than in the conventional logging operation (without residue recuperation) (Dryade, 1980).

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[1] diameter breast height

Harvesting itself is classically considered as a regeneration technique. Clearcutting systems are designed to achieve restocking, with or without additional help, on a high proportion of cutovers (Schultz, 1973). Artificial aids are applied where natural means are deemed likely to fail or to create an unacceptable delay. Classical aids for restocking a stand are:

. scarification: highly mechanized process capable of covering large areas quickly. It exposes mineral soil for a quicker germination of seed contained in the top remaining on the cutovers.

. slash burning: restocking technique sometimes used on slope too steep for scarification. Might stimulate aspen suckering.

. artificial seeding: seeding in wintertime by aerial means or terrestrial (snowmobile) of indigenous or exotic species.

. planting: areas which have failed to restock naturally or through other treatments are reforested by planting of indigenous or exotic species. Planting can be done mechanically on level ground or by hand on steep slope.

Scarification and planting are likely the most effective aids to regenerate a stand. Scarification however necessitates the presence of residual tops in order to be successfull. In the Complete Forest Concept, tops and branches will be recuperated.

Once the site has restocked, several activities could be undertaken for their improvement: application of chemical fertilizer for increased yield, spacing of immature stands, commercial thinning. In our general concept, residues could be extracted from these operations. However predicted volumes of residues will be low and will not be worthwhile in the boreal forest region but might be interesting in southern forest regions closer to market. Spacing and thinning usually reduce basal area and canopy cover of the overstory.

Finally, when trees are mature, they are harvested and residues (tops, branches,...) are logged for energy conversion. It is predicted that lower volumes of debris will be available in these second-growth stands.

5.2.2- Road construction and uses

5.2.2.1- Description of activities

Construction, operation and uses of forest roads are rather will known activities. Their interactions with wildlife have been documented by many authors across Canada. In the view of the Complete Forest Concept or other alternatives (Short-Rotation-Intensive Culture and Management of Native or Exotic Species on Short Rotation), this first activity should be executed with the same criteria than the conventionnal forest operations. The intensification of specific activities to produce maximum biomass from the forests should however contribute at different degree to intensify their uses and raise the frequency of users (worker, hunter, fisherman, berry picker,...). Furthermore, the management of new territories should increase the number of forest access roads mainly in the boreal forest regions.

These roads are designed and built to support heavy traffic. Standards and specifications are generally divided in two categories: permanent (10 year and over) and temporary (summer or winter) roads (Table 27). For the purpose of this analysis, differences of specifications (right-of-way, width, gravel thickness, grade,...) for each class will be discussed partially in the following discussion of interaction. Activities related to forest roads are usually divided in different operations which include:

- location and surveying
- right-of-way clearing
- grading and ditching
- borrow pit operation
- temporary access road
- culvert and bridge installation
- trucking
- road maintenance
- human presence.

Location and surveying

This first activity is of a great importance in the process of building a forest road since it can have a direct and indirect influence on all biophysical resources (quality of water, sensitive surficial deposits, drainage pattern,...) including wildlife (mammals, fish, birds, special interests and endangered species) and human values (aesthetic, archaeological, historical and recreational) (Schultz, 1973). Location should take in consideration all these factors in the planning of the road. Sensitive wildlife habitats for fish, waterfowl and game animals should be surveyed along different routes in order to identify the less damaging alternatives. As stated by Curran and Etter (1976), objectives of the survey would be to make observations and collect sufficient data to identify sensitive areas along alternate rights-of-way and rate them according to their susceptibility to disturbance. The survey should also identify the nature of controls that will be required to minimize adverse effects if a sensitive area must be traversed. The results of wildlife investigations should provide the basis for identifying the extent of critical and sensitive wildlife areas (wintering ranges for moose, waterfowl nesting, rare and endangered species,...). Changes to the preliminary route alignment can be suggested to avoid critical areas, and protection measures required in the sensitive areas can be stated.

Right-of-way clearing

This activity consists in removing all trees and shrubs from the right-of-way. In the perspective of complete forest biomass utilization, all commercial and non-commercial trees and shrubs should be utilized. Formerly non-commercial trees and shrubs were either burned or buried on site.

Grading and ditching

Grading of a road comprises all earthwork operations: excavation and fill requirements along any section of the road, depending upon the terrain and the proposed road-grade standards. It also includes the removal of the top soil and ditching. The maximum bared width varies from 9 to 27 m depending on road class.

Borrow Pit

The most economical method of construction is to balance cut and fill sections. Where right-of-way material is insufficient, it is borrowed from appropriate surrounding surficial deposits. Interpretation of aerial photographs easily permit the location of potentiel borrow pits (Gendron, Drolet, 1979). As the route location is often influenced by the availability of such material, the choice of borrow pits is made at the first step of planning. Field work is also undertaken to establish the quality and the exact amount of material. Once established, the chosen sites are cleared of trees and shrubs, stumps and top soil are removed. Forwarding material to the road requires the building of temporary access roads.

Temporary access road

A temporary access road is usually built within the right-of-way in order to execute specific works (bridge, culverts, dynamiting, ...) and accede to borrow pits. Building such a road necessitates cut and fill operations as well as temporary crossings of rivers and streams. For winter operations, these access roads could be made of ice and snow. In other seasons, temporary crossing should be done on rocky or gravel beds, otherwise temporary culverts, bridges or logs lying on the bed of the stream should be installed.

Culvert and bridge installations

The quality and overall erosion resistance of a road depends greatly on the planning and installation of drainage systems. Streams, rivers and wetlands can be crossed either by bridge, culverts or fillings. Installation can require partial filling of a stream bank which reduces the width of stream beds or even changing the location of the river or stream bed. In all cases, maintaining free upstream passage for migrating fish at crossing sites is extremely important because it can mean the differences between the continuation or elimination of fish utilization in a stream (Dane, 1978). The season when these structures are installed is also important because it could impede fish reproduction and migration. In designing structures, the objective should therefore be, to minimize such changes in natural conditions (Curran and Etter, 1976). The decision on whether to install a bridge or culvert over the smaller streams is a difficult one. Over streams with a known fishery resource, bridges are preferred. Culverts, however, are usually much less expensive.

Trucking

Trucking is of course the object of forest access road. In the Complete Forest Concept, one does not foresee major modifications in the weight or size of trucks, the intensity of traffic, or the allowed speed or uses for recreational purposes.

Road maintenance

Grading and maintaining the road surface is the principal maintenance operation. Dust control by oil or chemicals will increase driving enjoyment and safety. Drainage and erosion control are also part of maintenance operations; culverts must be checked for obstruction by debris or the accumulation of sediment. Finally, ice control, snow plowing and blowing are specific winter maintenance where needed.

Increase in human presence

Construction of new forest access roads generally contribute to opening new territory to general public. Companies and governments accepted the use of forestry roads by the public. These are used for hunting, fishing and for other recreational activities.

5.2.2.2- Description of interactions

Organized view of interactions between forest road activities and wildlife of concern is presented on Table 28.

INTERACTIONS BETWEEN FOREST ROAD ACTIVITIES AND WILDLIFE SPECIES OF TERRESTRIAL LIFE FORMS (1.1 TO 2.8)

Effects of road construction activities on terrestrial wildlife species are stated as being of low intensity by authors. Schultz (1973) indicated that road construction and use are considered generally innocuous to large mammal populations (caribou, moose, elk, deer, bear). Road surveys, clearing, grading, ditching,... are of short duration and on confined areas. Schultz (1973) also noted that their effects are shown as medium threat or not appreciable effects. Recurring activities such as road use and maintenance represents however a medium threat. In fact some species show a low tolerance to human presence. Although their specific habitat remains untouched, this presence could affect their behaviour.

An increase of human presence thus represents the major threat on terrestrial wildlife species. For instance, accessibility increase makes Grizzly bear populations more vulnerable to hunters, invariably artificial food sources are introduced which alter bear behavior and create problems, and finaly disturbance to critical feeding or denning sites will disrupt movement, home range and behaviour in general, again leading to increased conflict with man

Table 28. Interactions between forest road construction and wildlife: description of effects and mitigative measures.

Life form	Activity	Direct effects	Indirect effects	Mitigative measures
Terrestrial (1.1 to 2.8)	Construction	. Loss of productive land . Destruction of habitat of low density bird and animal species. . Attractiveness of edge habitat for some birds and mammals.	. Loss of a part of wildlife . Loss of wildlife	Locate the roadways through areas of lowest capability for wildlife and away from special habitat of rare, threatened and endangered species.
	Trucking and maintenance	. Collision with wildlife . Attractiveness of ungulates to road salt . Disturbance to animal and bird population (noise) . Interruption of nesting . Disturbance of wildlife movement	. Loss of a part of wildlife . Increase collision probability . Moving of sensitive species away from roads	Fencing critical areas, warning signs, speed control and other measures which may be appropriate to special wildlife.
	Increased human presence	. Overhunting . Harassment	. Loss of a part of wildlife	. Locate roadways through areas of lowest capability for wildlife and away from special habitats of rare, threatened and endangered species . Elaboration of strict hunting regulations while planning the road . Road closure when unused . Sensitization of workers and recreationnists to wildlife problems
Terrestrial and aquatic (3.1 to 3.5)	Construction, trucking and maintenance	. Loss of productive habitat (riparian zone) . Disturbance of birds and mammals . Collision with mammals, birds, amphibians, reptiles	. Loss of wildlife . Loss of part of wildlife	. Locate roads away from riparian zones . Keeping of a green belt between road and stream or riparian zone . No construction during nesting period . No access half-mile limits around nesting colonies . Fencing critical areas, warning signs, speed control,...
3.2 and 3.4		. Increase siltation and water temperatures	. Loss of part of fish food supply	. Apply measures for aquatic life forms
3.1 to 3.5	Increased human sence	. Overhunting . Harassment	. Loss of a part of wildlife	. Sensitization of workers and recreationnists to wildlife problems and strict hunting regulation
Aquatic (4.1 to 4.3) (4.1 and 4.2) Coldwater fish	Right-of-way clearing	. Expose soil to erosion and increase sediments load . Increase water temperature	. Increase gill damage and fish mortality . Decrease spawning areas . Reduce eggs and alevins survival	. Keeping of an untouched green belt between road and streams . Interdiction of heavy machinery to circulate in green belts . Piling up wood and residues away from buffer zone (60 m)
(4.1 to 4.3) (4.1 and 4.2) Coldwater fish	Grading, surfacing, borrow pit, temporary access road	. Exposes soil to erosion and increase sediments load . Increase water temperature		. Location of temporary access road within the right-of-way limits . Use of temporary stream crossings on snow and ice in winter. In summer on solid bed or with the help of logs or organic soil. . Rehabilitation of disturbed sites . Stabilization of instable soils using herbs or shrubs . Location of borrow pits away from water bodies
(4.1 to 4.3)	Culverts and bridge installation	. Unsufficient flow through culverts (low water) . Increase water velocity . Provide a catchment area for debris . Provide an excessive free fall	. Obstruction to fish migration and spawning	. Building bridges is preferable to culverts . Turning aside streams should be avoided . In culverts, water velocity should not exceed 1 m/s during spawning season . Installation should be done uniformely without creating obstacles or free fall to permit fish movement
	Trucking and maintenance	. Spilling of toxic products (oil, chemicals) and dust into water	. Increase fish mortality	. Location of fuel tanks at a minimum of 100 m from any water body . Storage of chemical products in areas where spilling cannot reach water bodies.
	Increased human presence	. Overfishing	. Loss of a part of wildlife	. Control of fishing activities

(Macey, COSEWIC, 1979). Novak (1974) attributed the decline of the Cougar in eastern North America to persecution by man; this endangered species can also be influenced by a greater accessibility of the Boreal Forest Regions.

Greater accessibility will also raise hunting pressure on wildlife. Thiessen (1975) attributed the decline of elk population directly to overhunting and overall harassment. Scaufe (1980) concluded that the forestry roads have a direct effect on Moose populations in that hunting pressure increases with the additional access. Thus, there is an indirect relation between forest road and ungulates populations.

Barber, Stelfox and Boden (1975) stated that increased human activity resulting from increased access along the Churchill River in Saskatchewan would represent the most significant factor in any potential impact on hunted species: wolverine, black bear, woodland caribou, moose, beaver, mink, otter. Also both Bald Eagle and Osprey could suffer decreased productivity because of the increased human activity that would result from improved access. These birds are particularly sensitive to human activity in proximity to nest sites during the nesting season (April 1st to July 31st). Finally waterfowl species that prefer isolation such as the Common Loon, would decrease in density if there was an appreciable increase in human activity.

Along the same line of thought, Bunnel and Eastman (1976) stated that the major influence of logging roads appears to be the provision of access to hunters. A survey in the white spruce type of Alberta, established that 28% of the moose kill was taken within one mile of a road where 80% of the hunting pressure and 18% of the land occurred. Observations in British Columbia also demonstrated these facts. However, the impact is more severe on populations that cannot sustain a high harvest rate (Grizzly, mountain goat,...). Access into the remote areas frequently lead to near over-harvest of these populations before harvest policy is effectively modified.

Another fact stressed in the Bunnel and Eastman report is the response of particular wildlife species to roads themselves. For instance, Rocky Mountain elk and black-tailed deer appear to avoid roads even when there is no traffic whereas other species such as black bear and moose appear to use roads as travel routes.

The alignment of road through ungulate winter range could interfere with game movement including disturbance and possibly the obstruction of animal movements resulting from berms, cutbanks, sidecast rocks and excessive grading in the vicinity of game crossings. The loss of habitats providing high class winter range could have a significance that need only be negligible providing that wasteful construction methods are prevented and locally sensitive areas of habitat are given apprcpriate protection (McDonald, 1977).

Road trucking and maintenance vs terrestrial life forms (1.1 to 2.8)

Road trucking and maintenance appear to cause mortality. Grenier (1973), showed that the moose kill by collisions in Laurentides Park of Quebec was directly correlated with traffic intensity and accounted for 15 to 20% of the population living near the road.

The loss of birds through road kill appears also to be a significant mortality factor. The Borrowing Owl and the Great Gray Owl are examples of species that are affected by accidental collison with vehicules. Other game and non-game birds are commonly found dead along highways and to a lesser extent along forest roads.

A survey of available literature on road and rail traffic effects on wildlife reveals that astonishing wildlife losses can occur on highways and railways. For example, over 1,5 million deer are believed to be killed annually on highways in North America together with uncounted millions of smaller species (B.C., Ministry of Environment, 1976 - 1977).

Road salts used in winter appear to attract wildlife. Bunnell-Eastman (1976) stated that although there is significant highway mortality for some species (ex.: Bighorn sheep) during the winter when roads are salted, logging roads in British Columbia do not appear to contribute significantly to road kill.

INTERACTIONS BETWEEN FOREST ROAD ACTIVITIES AND WILDLIFE SPECIES OF TERRESTRIAL - AQUATIC LIFE FORMS (3.1 TO 3.5)

Many species related to these life forms are directly disturbed by the loss of shelter, food and water availability when roads are built in the surrounding of water bodies or in riparian zones. Forest roads in riparian zones will reduce the effectiveness of the zone as habitat for many wildlife species. This results from alteration in the vegetative complex and increased disturbance from traffic along the road. Increased sedimentation from road construction may be detrimental to water quality and hence to aquatic life (Thomas, 1979). A diminution of fish population could produce negative effects on life forms 3.2, 3.4, 3.5 comprising carnivorous species.

Furthermore, road location along river banks and across wetlands can produce negative effects on nesting waterfowl as these species are extremely intolerant to disturbance. Mechanical disruption and channelization can reduce, raise or eliminate the water holding capacity of wetlands and therefore its capacity for recharge of ground water (Henegan and Harmon, 1971). This increased drainage may also alter vegetative cover and therefore minimize the attractiveness of a given area to endemic species (Barstow, 1974).

INTERACTIONS BETWEEN FOREST ROAD ACTIVITIES AND WILDLIFE SPECIES OF AQUATIC LIFE FORMS (4.1 TO 4.3)

Implantation of a forest road can particularly affect aquatic wildlife species, since they rapidely react to any modification of habitat components (Dryade, 1980). Sedimentation generated by erosion and raise of water temperature are the two major sources of disturbance. Bridge and culvert installations, temporary access roads and maintenance are all activities that can generate such disturbances.

Logging roads are the major contributors to increased sedimentation of streams which may seriously impair the capacity of streams for fish production (Chamberlain, 1942). Effects of road grades (favorable or adverse) was also an important factor (Dryade, 1980).

Right-of-way clearing, grading and ditching and borrow pit operations.

Right-of-way clearing exposes soils to erosion and also increases the rate of erosion by reducing precipitation interception. As a consequence, greater stream sediment loads can be expected (Rowe, 1974). Gill damage, increased incidence of «fin rat», and greater mortality of fish are all attributed to high concentrations of suspended sediments (Cordane and Kelly, 1961). These authors indicated that even moderate sediment deposition reduces the survival of eggs and alevins and decrease flow through the gravel, thereby limiting the supply of oxygen to the eggs. Ritchie (1972) also noted that water turbidity affects fish directly through gill damage and mechanical abrasion. Rosenberg and Snow (1975) stipulated that suspended sediment concentrations in most flowing waters should not exceed 80 mg/L to assure protection of aquatic wildlife.

Culverts, as such, do not present problems for fish, their improper installation, however, can cause them to become barriers for migration. Rowe (1974) indicates that culverts can create four basic problems:

- culverts can be installed in such a manner that during times of low water, flow through the culvert is not sufficient for fish passage, as a result of water losses under the culvert.

- fish passage can be impeded by increased water velocity resulting from culverts placed on too steep a gradient or culverts that are too small to adequately handle stream discharge.

- culverts usually constrict channel width and as such provide a catchment area for debris. The build-up of debris can clog the structure, thus making it a barrier to migration.

- excessive free fall at the culvert outlet presents a further obstruction to fish movement.

Bridging is preferred for stream crossings since it avoids those problems that are inherent in culverts, namely gradient, velocity and free fall. Bridges, however, can have deleterious effects of fish population if care is not taken during construction activity:

- destruction of spawning grounds, due to use of heavy equipment in the stream bed.

- excessive siltation of the stream due to construction practices.

- introduction of toxic material such as lime and creosote.

Road maintenance vs aquatic life forms (4.1 to 4.3).

The principal activity that can influence aquatic species in maintening roads is the use of salt to prevent ice formation. Road salt, in addition to being a serious contaminant, may release mercury from bottom sediments (Feick et al., 1972). Samples analysed in the state of Maine indicated that wells and farm ponds were seriously contaminated with chloride ions. Concentrating of the ions in rivers apparently were not influenced by application of sodium chloride. In lakes salt may increase density of water, creating and reinforcing density gradients which many inhibit spring and fall overturn (McConnell and Lewis, 1973). It is known that the overturn process is an important factor in redistributing oxygen in lake. In the rivers or streams, salt is quickly diluted so that the normal chloride level remains unchanged (Voorde *et al.*, 1973). However additives, used to prevent corrosion, in high concentrations, may be toxic to fish. On forest roads, salt is used only in strategic spots. Sanding is a more common practice. Thus the effect of toxic chemicals should be less important than on public highways.

Drainage and erosion control, part of a road maintenance program are activities identified as producing a positive effect on fish, since it usually removes debris obstructing culverts and prevents mineral soil from reaching water courses.

Increased human presence vs aquatic life forms (4.1 to 4.3).

In Alberta, Schultz (1973) considered that the effect of fishermen on fish as a medium threat because current regulation of fishing appears inadequate to meet future needs with extended access and sports fishing pressure at favored spots.

Road construction and use vs coldwater fish (life forms 4.1 to 4.2).

Direct effects of road construction being mainly erosion and increase in water temperature (Dryade, 1980), species grouped under these life forms (i.e. requiring cold water for one or many specific requirements) are susceptible. Species inhabiting small rivers and creeks are more sensitive because of the low water volume to heat.

The salmon family is included in these life forms. This family is specifically known as inhabiting clean, cold rivers and streams. Being carnivorous and thus predators, they are highly sensitive to any modification of their habitat (Dryade, 1980). The requirements for good trout and salmon production (Rowe, 1974) are:

- the available food supply of a stream (depends on clean, cool and well oxygenated water).

- a concentration of dissolved oxygen, usually above 7 ppm for optimum production.

- a shelter provided by undercut banks, deep pools, rocky areas and overhanging vegetation (especially important to young fish).

- a water temperature between 0° to 20°C (most critical for spawning which range between 5° and 10°C).

- a clean loose gravel through which water can readily percolate for spawning success.

- rearing or nursery areas that provide ample food supply and shelter for young fish.

Effects of siltation on food supply

Road construction through siltation could affect food supply. Barton (1974) demonstrated no significant change in benthic invertebrate populations. A close monitoring before and after construction in a small stream of southern Ontario has shown no change in numbers of riffle macroinvertebrates. Chutter (1969) observed a decrease in invertebrate species composition but not in overall abundance. At the opposite, Cordane (1961) indicated that the benthic invertebrates and mussel populations are greatly decreased or eliminated by sediment deposition.

Ritchie (1972), pointed out that turbidity can affect food either by decreasing the numbers of kinds of bottom organisms or by reducing the ability of fish to find food. Rowe (1974) also indicated that streams with heavy sediment loads show marked reductions in productivity of fish foods. Brodie (1973) noted a change of species. The increase of population of more tolerant species however compensates for the loss of more sensitive organisms. Salmonid diets generally changed in response to changes in the availability of food items.

Effets of siltation on spawning

Trout and salmon spawn in gravel that is clean and well oxygenated. Sediments generated from roads clog spawning areas and choke eggs and alevins (Dryade, 1980). A laboratory test, using incubating canals, observed a 85% mortality rate for salmon eggs when 15 to 35% free space in gravel material were filled in with sediments (Shelton and Pollock, 1966). Peters (1963) have related this rate of mortality to a drop of oxygen concentration. They established that the intragravel dissolved oxygen concentration decreased in relation to the increase in sediment concentration and produced a progressive increase in trout embryo mortality. Phillips (1971) explains these facts in 4 major points:

1. Filling the interstices reduces interchange between surface waters and waters within the gravel bed. This reduces the supply of dissolved oxygen to the eggs and interferes with the removal of metabolites (carbon dioxide and ammonia).

2. Sediment also forms a barrier to fry emergence by blocking the route of egress.

3. Low dissolved oxygen and the physical barrier effect of sediment appear to be additive in reducing survival.

4. Survival after fry emergence is impaired because of a loss of escape cover and a reduction of organisms for food.

Effects of temperature raise

Dryade (1980) stated that water temperature could be highly affected by forest road construction. This operation often creates unshaded stream reaches where temperature increases rapidly. Thus, total length of road along streams and rivers appears to be critical. Species whose metabolism requires cool water (life forms 4.1 and 4.2) are sensitive to this specific parameter. Salmonid inhabiting streams (life form 4.1) are more particularly concerned by temperature variations. As well as inducing direct mortality of fishes, adverse water temperature influences the level of dissolved oxygen. Forest access roads should generate a significative impact if located along water course implying the removal of streamside vegetation. Such a practice increases maximum water temperatures by exposing streams to increased direct solar radiation.

Krammes and Burns (1973) indicated that dissolved oxygen concentrations were not adversely affected by concentration activities or by removal of streamside vegetative cover. Burton and Liken (1973) stated that following strip cutting, on a sunny day, the stream rapidly increased by 4° to 5°C in the cut strips. Chapman (1962) specified that the removal of riparian vegetation causes greater temperature extremes in the affected streams. Also, Gray and Edington (1969) stated that the lack of forest cover can be the decisive factor in determining the temperature of small streams. Forest roads could therefore affect behaviour and survival of salmonids, especially if located along small rivers or streams.

Within the Complete Forest Concept, effects of primary and secondary roads are as important as the conventional harvesting systems.

Other interactions

As mentionned previously, the increase of suspended sediments could initiate and create gill damages to salmonids (Ellis, 1936). Much of the environmental concern about roads has focussed on the road-stream intersection. The poorly located, poorly sized and poorly installed culverts on many roads also hamper the free movement of fish (Env. Coun., Alberta, 1979). Also the spilling of toxic chemicals or oil could also generate drastic effects. Oil spills from fuel dumps have a major influence on the aquatic habitat (Hutman, 1972). Bury (1972) found that an oil spill into a forest stream resulted in a very large kill of both vertebrate and invertebrate aquatic life.

Interactions between road construction and the salmonids are generally well identified mainly because of their recreational and commercial value. Although environmental effects described for this family could be applied to all species of life form 4.1 and 4.2, some species might react differently. This might be the case of threatened species included in these life forms. McAllister and Gruchy (1977) indicated many unanswered questions on spawning and population trends of Shortnose sturgeon. The Atlantic whitefish found in very localized water bodies of Atlantic provinces (Tusket river system and Millipsigate lake) should not be influenced as this species is already protected by a special regulation in Nova Scotia.

Road construction and Use vs Warmwater Fish (life form 4.3)

Species grouped under this life form include all warm water fish and fish using «other habitats». Generally, these species are more tolerant to temperature changes. Activities that could modify water temperature described previously will not generate the same negative effects than for coldwater fish. Positive effects could evenly be observed. Aithken (1936) noted that a gradual change in water conditions caused a modification in species composition. Coldwater fish were gradually replaced by species more tolerant to warm water conditions and increased turbidity. Forest roads would thus generate a lower impact on these species (Dryade, 1980).

If some species are more tolerant to water heating, others are more sensitive to turbidity. As turbidity and sediment deposition increased, the small mouth bass and other «clean water loving» fish were replaced gradually by quillback carp, gar and catfish (Aithken, 1936). Buck (1956) added that the largemouth bass is also affected by water turbidity. From these brief indications, erosion increasing turbidity can create negative effects on these species. More specific research should be undertaken.

Rare, threatened and endangered species included in these interactions are not much documented. Only the Cutlip minnow, and the Black redhorse are described as being intolerant to turbidity. The Copper redhorse and the Shorthead sculpin are threatened by water pollution and human activities (McAllister and Gruchy, 1977).

5.2.2.3- Mitigative measures and general recommendations

As described previously, effects of road construction and use are quite well documented. Mitigative measures to attenuate negative effects have also been proposed by authors. Although these measures are quite specific, they first imply a survey of the wildlife resource in possible alternative road corridors. Special attention should be given to rare, threatened or endangered species, migrating corridors, ungulate winter range, waterfowl nesting areas and denning sites for bear, wolf,.. (Curran and Etter, 1976). A survey of sensitive aquatic fauna should also be part of basic data. As stated by Curran and Etter (1976), the results of wildlife investigation should provide the basis for indentifying the extent of critical and sensitive wildlife areas. Changes to the preliminary route alignment can be suggested to avoid critical areas, and protection measures required in the sensitive areas can be stated. These measures could be applied to species and life forms of terrestrial, terrestrial and aquatic, and aquatic habitats.

TERRESTRIAL LIFE FORMS (1.1 TO 2.8)

Road location and construction

The most effective means of reducing habitat losses would be to locate the roadways through areas of lowest capability for wildlife. Losses often result from unnecessarily destructive construction methods or improper location of borrow pits or work roads. Matters of this sort should be considered early in the planning process.

Since information is usually scarce on the distribution and biology of rare, threatened and endangered species, any observations should be communicated to provincial or federal wildlife biologists concerned with these species.

The Environmental Council of Alberta (1979) recommended the preparation of a master road system plan in the Green Area. The development of such a plan for all roads in an area should eliminate a lot of duplication and result in some economy. This would require some difficult long-range planning but would be justified by some real benefits - lower cost, less and taken out of timber production, less environmental damage and less harassment of game. The Environment Council of Alberta (1979) stated that a Government body must be made responsible for the overall coordination of road planning in the «Green Area».

Trucking and maintenance

The main effect of trucking and road maintenance on terrestrial wildlife is road kill. The most effective known means of preventing collision mortality is to keep roadways out of high capability habitat for wildlife, fencing through sensitive areas where sight distance is short (curves, uphill,...), warning signs, speed controls and other measures which may be appropriate to particular conditions.

Although road salts are not commonly used for forest roads, their uses should be avoided near areas with high potential as winter habitat for ungulates. Collision probability should then be considerably diminished.

Snow plowing or blowing operations should avoid creating continuous snow banks on either side of the road which could obstruct wildlife passage.

Increased human presence

The most important source of impacts due to roads is increased access to hunters, fishermen and other recreational activities which contribute to modifying game population and to drive out species sensitive to harassment. Measures should be elaborated to limit human presence where necessary and to control hunting and fishing activities by defining wildlife harvest policy before roads are built. For instance, harassment of goats, cougar, owls, waterfowl must be minimized during critical periods of the year. The Fish and Wildlife Branch of British Columbia (1979) suggest the application of educational programs to increase public awareness of potential hazards created by these animals.

Scaufe (1980) stated that forestry roads have a direct effect on moose populations in that hunting pressure increases with the additional access. Designated rates can be used and stricter hunting regulations should be applied to alleviate the problem. It is little use to spend money mitigating habitat damage if the animal population that might have benefited is drastically reduced by uncontrolled hunting. Schultz (1973) stated that the deliberate destruction or «putting to bed» of roads no longer used may be desirable as a fish and game management tool. It is difficult to close roads temporarily. If a road is to be used again, it must be maintened for erosion control. Where a road is not going to be used again within a reasonable time, it should be destroyed and revegetated (Env. Council of Alberta, 1979).

However, Coggins (1975) stated that apparently closed roads were favoured by most hunters and did little to increase elk survival because the number of hunters increased.

Increased access also have an influence on rare and endangered species. For instance, Martin (COSEWIC, 1978) recommended protection of individual Peregrine Falcon and their breeding habitats. A population inventory of this bird should be made and guidelines should be developped for its protection and management prior to any development. Skinner (COSEWIC, 1978) also suggested the reintroduction of the American marten where human access is limited in Newfoundland. It should then be important for the management of this species to identify potential territories and minimize road construction in these areas.

The Kirtland's Warbler is considered one of the world's most endangered bird species. Chamberlain (COSEWIC, 1978) suggested a federal-provincial cooperative census of areas having a high potential for occupation by this species. Although this bird is actually located in a very small portion of Canada, it would be essential not to develop sites identified as having high potential for breeding territories.

Cougar are endangered in Eastern Canada, populations not being confirmed and documented. When creating new access to an area, measures should be undertaken to publicize cougar to work crews and visitors, asking for observation reports and urging them not to shoot cougars.

In grizzly range, road construction in high density areas or in critical feeding areas should be avoided. Also, to avoid overhunting, imposition of quotas is considered necessary (Olson and Haefs, 1978). A greater accessibility also implies the introduction of artifical food sources which alter bear behaviour and creates problems. Public education and control of human activities, including incineration of garbage at work camps, are necessary to protect this species.

Finally, other declining species should be taken into consideration when planning a road. For instance, roads should be kept away from the bottom of cliffs or slopes used by raptors for nesting.

TERRESTRIAL - AQUATIC LIFE FORMS (3.1 TO 3.5)

Recognizing the intensive utilization of riparian habitats by wildlife and the rather low proportion of these habitats compared to total forest habitat, any modification of them , such as road construction, will result in drastic losses of wildlife. Mitigative measures related to species inhabiting these zones aim to protect the integrity of river banks and wetlands. Measures could also be taken to control overhunting and general harassment of wildlife.

Location and construction

During this first step of planning, rivers, streams and wetlands should be identified and classified according to their potential for wildlife. Mapping of habitats should be at a proper scale to show the more sensitive sites.

Road construction and maintenance

The loss of productive habitats would require specific mitigative measures to attenuate negative effects.

The most effective measure would be to locate roadways at a distance from sensitive areas. When topographic and management conditions require crossing or paralleling watercourses or wetlands, managers need to determine how much riparian habitat is already impaired by such roads. This can be done by comparing for instance, the percentage of streamlength alongside roads with the percentage of streamlength without roads (Thomas, 1979).

A good distance between road and sensitive riparian zone and wetlands could also be beneficial to road maintenance since it reduces probability of flooding.

Riparian habitats being considered as very sensitive zones, the right-of-way clearings in these areas should be done with great precautions using light machinery. Any work should be undertaken within at least 30 m from river or stream banks. Other activities in this buffer zone should be minimized (stubbing, excavation, embankment,...) (Environment Canada, 1980). In all cases, borrow pits must be located outside of this zone.

Since waterfowl mainly inhabit riparian zones, they are intolerant to noise and other disturbance when nesting. So a schedule of road construction and wood transport should be prepared giving consideration to that period of the year.

Many species in these life forms are known as being rare, threatened and endangered. Some are most particularly sensitive to disturbance: Colonial nesting birds such as the White Pelican, Double-Crested Cormorant and Ancient Murrelet. Markham (COSEWIC, 1978) recommends a regulation which should «prohibit habitat destruction» and «human disturbance» and «no access half-mile limit» around nesting colonies during the nesting season for White Pelican. For this species, important foraging areas should be identified and protected from conflicting land use. The Double-Crested Cormorant should also be protected using the same restrictive measures.

The Trumpeter Swan, which is not a colonial nesting bird, requires large breeding territories. Loss of feeding and nesting habitats to filling or drainage is a mortality factor. A close surveillance of all known nesting areas should be maintained to prevent the loss of any of them to human desecration.

Increase of erosion increases siltation and water temperature having a direct negative effect on aquatic fauna, species included in life forms 3.2 and 3.4 will be affected. In fact, fish is a very important part of their diet. Mitigative measures recommended for aquatic habitats should be applied to attenuate negative effects.

Road use has the effect of increasing wildlife mortality by collision with trucks, cars and other vehicules. Reptiles and amphibians comprised in life form 3.5 are highly susceptible of being involved by road kills. Also the loss of productive habitats might be very important to these species. Research of literature or advice from specialists have demonstrated that there are actually no extensive studies done or available on the effects of forest roads or highways on reptiles and amphibians populations.

Increased human presence

The rise of human presence usually increases the hunting pressure on waterfowl and harassment of other wildlife species.

Overhunting could be limited by road closure, local bag limits and strict enforcement.

Harassment of semi-aquatic fauna can also generate important effects on reptiles and amphibians since they are often killed by many people on sight. Only through public education programms can this behaviour be changed (B.C. Min. of Env., 1980).

The human presence also has an effect on rare, threatened and endangered birds such as the Common Loon, Trumpeter Swan, Double-Crested Cormorant,... The most efficient means of reducing negative effects would be to avoid riparian zones where sensitive species to human disturbance are present.

AQUATIC LIFE FORMS (4.1 TO 4.3)

The main effects related to road construction being modification of aquatic habitats, measures to attenuate negative effects should be concentrated around road location and construction methods.

Location and survey

Sabean (1976) stated that problems caused by forest harvesting activities can be largely ameliorated by proper design and lay-out of roads. The magnitude of loss of habitat could be reduced significantly by treating streams as an integral part of the total forest environment. Carefully planned and constructed roads contribute negligible amounts of turbidity (Eshner and Larmoyeux, 1963).

Roads must be located to ensure that vegetation is not removed or disturbed between the construction activity area and any water body (Rowe, 1974). Sabean (1976) added that no roads are to be built in green belts except where stream crossings are necessary; in this case the stream crossing should be made with as little disturbance as possible. The width of green belts change along with the importance of the stream, topography and provincial legislation. In Saskatchewan, for instance, a 15 m buffer zone on small streams is required and 90 m for more important rivers (Anonymous, Saskatchewan, 1978). In Quebec, Leblanc, Julien et Gélinas (1979) recommended a minimum of 60 m between water courses and the right-of-way. Also, the road should not be located in narrow valleys or on unstable soils. These authors recommended avoidance of long, unbroken slopes because erosion of ditches and road surface can be severe on such stretches.

A survey of spawning and rearing areas should also be undertaken. Road location and also construction schedules should include procedures for minimizing disturbance of such areas.

The grade or steepness of the road is also an important factor in logging road location. Gentle grades permit timber to be harvested economically without damaging other natural resources (Wochenderfer, 1970).

Right-of-way clearing

In the right-of-way clearing process, non-commercial trees and slash is usually a problem. In the Complete Forest Concept, these residues will be salvaged. Thus all problems related to slash elimination will not be treated.

However, the vegetation must not be stripped completely at stream crossing areas. Ground vegetation should remain undisturbed within 30 m of the stream (Rowe, 1974).

Drainage ditches or push lanes are not to be extended to ponds or streams, vegetation cover should be maintained to permit settling of silt prior to its reaching streams or ponds.

Green belts must remain untouched. In boggy areas bordering streams, skidding with heavy equipment should not be allowed. Cutting by chain saw and hauling up by cables, however, could be allowed up to 15 m from the stream (Groenewand, 1977). Clearing must not exceed the required space for surfacing, drainage and security of users (Environment Canada, 1980). If harvested trees and residues are not immediatly conveyed to mills, they should be carried out of the right-of-way and piled in an area at least 60 m from any watercourse (LeBlanc, Julien and Gélinas, 1979).

These measures, if properly planned and executed, should minimize water temperature rises, erosion and siltation.

Grading and ditching, borrow pit, temporary access road

Several measures can be applied to prevent negative effects related to these activities. The temporary access road should be located within the right-of-way limits of the road. Temporary crossing of streams should be made in winter on snow or ice bridges. In summer, the temporary crossings should be made preferably on hard stream beds (rock, gravel,...). Organic stream beds can be crossed on logs previously installed to increase carrying capacity. If significant deteriorations of stream crossing appears while operations are in progress it is necessary to immediately rehabilitate disturbed sites to reduce erosion problems. Removal of top soil should be minimized. Summit of slopes should always be rounded to allow an optimum drainage. Around culverts the filling material should never contain organic matters. Steep slopes and bottom of ditches should be stabilized. Finally, erosive material could be stabilized by using herbs or shrubs and backfill into ponds or streams and removal of gravel fill from either stream bed or bank must be avoided.

Existing borrow pits should be used first. When non-existant, borrow pits located in the vicinity of the road and at least 75 m from any stream should be used. These pits and related access roads should be provided with appropriate drainage systems to prevent erosion (Le Blanc, Julien and Gélinas, 1979).

Culvert installation

Building a bridge without putting pillars in the stream bed produces less negative effects than any other construction method and should be favoured. Approach works on stream bank should not reduce the width of the natural bed. If this is unavoidable, the overall width of streams should not be reduced more than 20%. Also, modifications of the transverse profile of the stream should be avoided. Diversion of streams must also be avoided. Bridges should be favoured over culverts when water velocity exceeds 1 m/sec. during spawning season (Le Blanc, Julien et Gélinas, 1979).

Specific attention should be given to the location, size and method of installing culverts to avoid diverting streams. Crossings should not be located where banks are subject to erosion

(Env. Canada, 1980). Culverts should be installed on a uniform slope, preferably following the existing gradient of a stream (Rowe, 1974). Generally, all culverts should allow fish migration and consequently culverts should be installed in seasons when migration is not occurring. A regular surveillance program should prevent any obstruction of culverts.

Trucking and maintenance

Rowe and Case (1978) recommended the location of facilities such as garages so that fuel and lubricants cannot enter any water body. Fuel tanks should be located at a minimum of 100 m from any water body. Deicing and dust control agents should be stored in areas where they cannot enter water bodies. Mechanical rather then chemical methods of brush control are preferred in the vicinity of water bodies (Rowe, 1974).

Increased human presence

Suitable regulations and surveillance of rivers and lakes may be necessary to prevent overfishing when building and operating a road in a new territory.

5.2.3- Forest biomass extraction

5.2.3.1- Description of activities

As described previously (5.2.1), activities related to biomass extraction will be divided in three major groups depending on the size of cutovers, the type of material extracted and the logging methods utilized.

. Size of cutovers:

- large clearcut (200 ha and over)
- medium clearcut (from 25 to 200 ha)
- patch clearcut (25 ha and lower)
- strip clearcut (from 20 to 200 m wide)

In provinces where size of cutovers are not reglemented, forest operators logically harvest all merchantable timber stands tributary to each road developped, starting with areas closest to the plant. Forms of clearcut generally follow the topographical contraints (river, steep hill,...) and of course the type and stand maturity.

. Type of material harvested

- stems
- tops and branches
- stump-root system
- snags (dead standing trees)
- logs (down woody material)
- unmerchantable trees or shrubs

Harvesting systems

Three harvesting systems have been considered for the present study: full-tree harvesting (stem - top - branches) in one operation, full-tree harvesting in two operations (first stems, then residues) and the complete-tree system which requires the extraction of the full tree from the ground, including the stump-root system.

The first (full-tree harvesting in one operation) which corresponds to the common sequence of operations in eastern Canada involves mechanical felling by feller buncher, movement of full trees by a grappel skidder and delimbing at road side by a mechanical delimber. The second (full-tree harvesting in two operations) could be divided in two sub-categories depending if the first operation is done according to the tree length or the shortwood methods. In the tree length method, trees are felled, limbed and topped at the stump and then skidded or forwarded to the primary landing for loading of for further processing. The shortwood method consists of power-saw felling, delimbing and cross-cutting into lengths (usually 2,4 m in Canada) and hand piling of the bolts produced. This still widely used method is being increasingly mechanized through the introduction of the stump processor. The machine fells, delimbs, tops and cuts at length at stump, the bolts being transferred automatically to an integral rack of the processor (Weldwood, 1979).

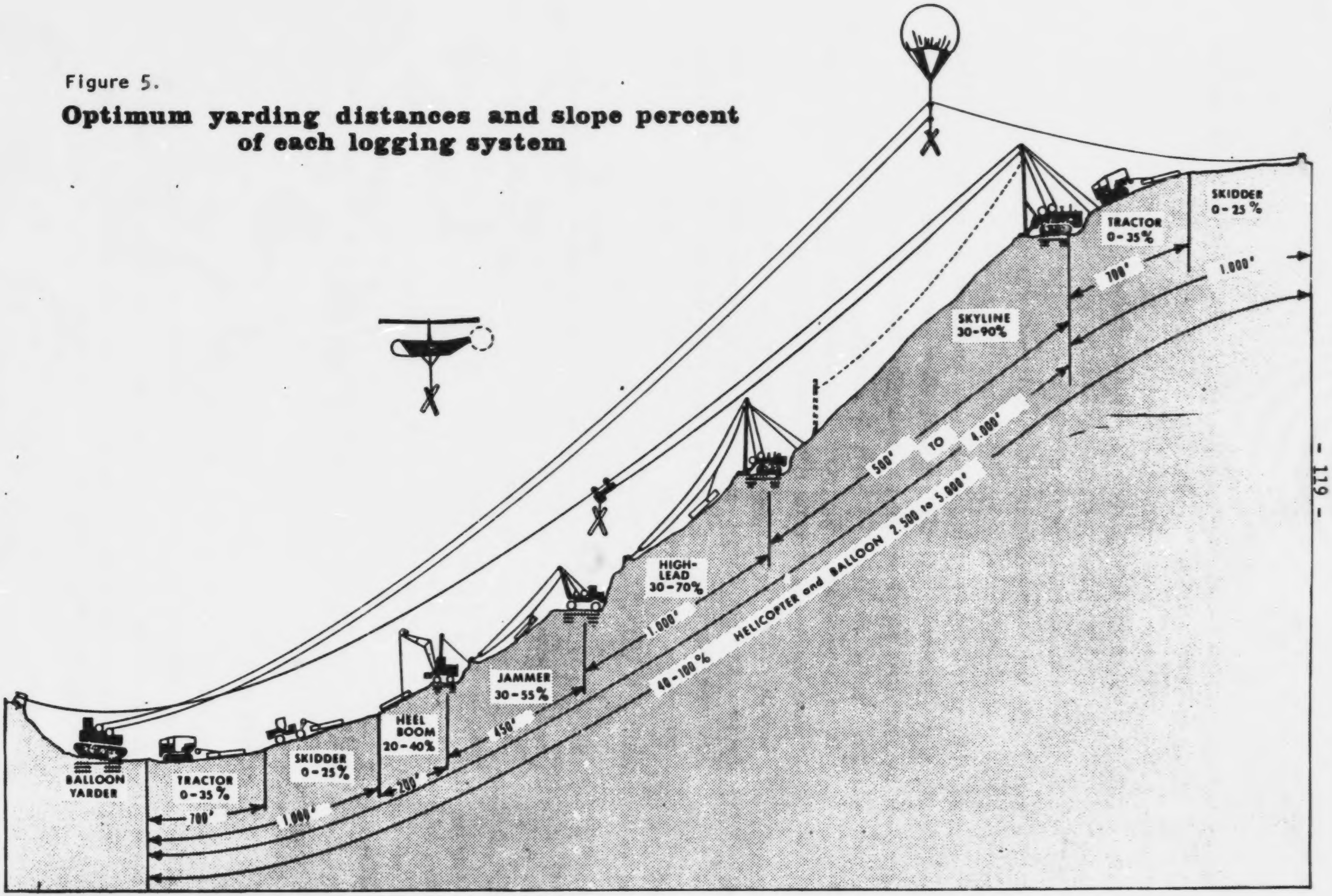
These systems and methods are mainly used in the boreal forest regions where stands are covering large uniform areas and trees are of low diameter.

In the Pacific Coast Forest, logging systems are recognized as unique. Figure 5 illustrates yarding distance and slope percent of possible logging systems (cable, highlead, skyline, balloon and helicopter yarding). In these forests, because of larger tree (and branch) sizes in many old-growth stands, tree-length or long-log-length logging are standard procedure. Delimbing and topping is done by power saw (Weldwood, 1979). Recovery of residues from these operations have not yet been implemented. Two broad lines of Research and Development are distinguished in literature (Nagle, 1980):

- totally new all-terrain systems, such as airborne platforms or very large crane

Figure 5.

Optimum yarding distances and slope percent of each logging system



SKIDDER 0-25 %
TRACTOR 0-35%
700'
1,000'
SKYLINE 30-90%
500' TO 4,000'
HIGH-LEAD 30-70%
1,000'
HELICOPTER and BALLOON 2,500 to 5,000'
40-100 %
JAMMER 30-55%
450'
HEEL BOOM 20-40%
200'
SKIDDER 0-25%
1,000'
TRACTOR 0-35 %
700'
BALLOON YARDER

Source: Studier and Binkley (1974).

- marginal changes to existing yarding, processing and hauling systems.

Possible expansion of current systems include:

- long-top logging to extract most of the residual bole,
- extra small chokers with existing rigging systems for high lead and ground skidding,
- relogging with lighter equipment, with variable leftover volumes, and on a range of forest and terrain conditions,
- new approaches to processing/hauling.

In the mixed forest zone (St. Lawrence - Great Lakes, and Acadian forest zone and Parkland) combine shortwood systems and tree-length are used to segregate products (saw logs, veneer logs and pulpwood). In these regions, trees are hand-felled, topped and delimbed at stump and carried to the landing with skidders or farm tractors. In addition residues are either cut in small pieces for heating purposes or chipped.

The Complete-Tree System (including the stump-root system) requires the extraction of the full tree from the ground. Usually, the lateral roots are sheared below the root collar so that the tree can be wrenched from the ground, aided by scissors grips and soil reaction pads. The complete tree (minus shallow lateral roots) is lifted clear and bunched for skidding. Trees are then transported to a washing station where they are washed for 30 minutes with two high pressure hoses to remove sand and other contaminants (Weldwood, 1979).

Fire control

In Canada, as over much of North America, a major objective of forest management has been the control and elimination of wildfires. In British Columbia, the objective of the fire suppression program is to bring all wildfires under control before 10 a.m. on the day following detection. In the same province progress made in fire protection to reduce the number of man-caused fires per 100 000 population has dropped from 209 in 1913 to 58 in 1976. Records for the past 10 years show that the fire suppression program has been 86% successfull in its initial attack on wildfires (B.C. Ministry of Forests, 1980).

In our conceptual model, fire prevention and suppression will be considered not through definite activities (direct fire-fighting, airtanker basing, air detection control,...) but considering the result which contributes to significatively diminishe areas annually destroyed by fire. In fact wildfires are at the origin of most coniferous even-aged stands in Canada and are thus an integral part of natural ecosystems evolution.

5.2.3.2- Description of interactions

INTERACTIONS BETWEEN FOREST BIOMASS EXTRACTION ACTIVITIES AND TERRESTRIAL LIFE FORMS (1.1 TO 2.8)

All forestry practices affect wildlife to some degree. The magnitude of impact from a particular practice depends upon the wildlife resource affected (e.g. energy, cover,...) and upon the trophic level and requirements of the wildlife involved. Many animals, particularly deer, moose and elk, benefit from the increased forage and browse available on clearcut sites. If the cutblocks are too large, however, the animals will avoid using the large central areas where they are too exposed and far from cover (Env. Con. of Alberta, 1979). Each animal has a different requirement for food, cover and reproduction. Lovejoy (1971) stated that no increase in total mammal population occurred after logging, although there were changes in the relative abundance of some species.

Positive or negative effects related to extraction practices can vary depending on whether one considers the short term or long term. Clearcutting, for instance, can be detrimental in the short term to ungulates while the following regeneration will generally produce a positive effect since the amount of available food will be increased.

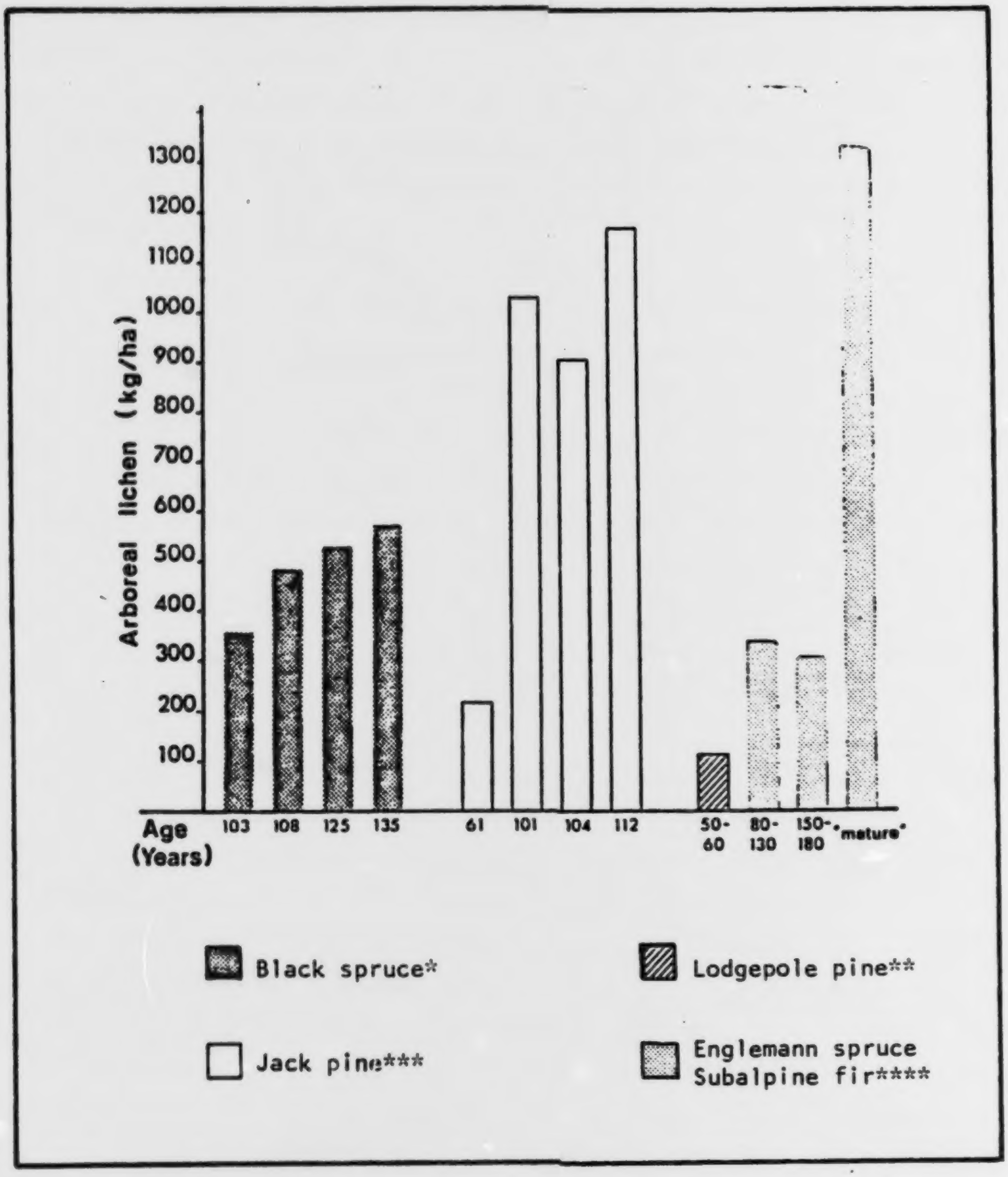
Life form 1.1 to 1.4 (Species inhabiting mature softwood stands)

Species classified under these life forms all require mature softwood stands to fulfill at least one specific requirement (reproduction, feeding, shelter,...). Logging activities can produce important negative impacts on species such as caribou, cougar, lynx, American marten, owls... Table 29 presents an organized view of the following interactions.

Herbivorous and carnivorous species which reproduce on or under the ground (life form 1.1 and 1.2) are affected by food and shelter losses. For instance, mountain or woodland caribou depends, in winter, upon tree lichens found only on mature spruce or fir (Schultz, 1973). Arboreal lichens were considered the critical winter foods of caribou because of the unavailability of other food stuffs due to excessive snow pack depths (Freddy, 1974). These lichens are greatest in high elevation stands 150 - 250 years of age. Stands younger than 150 years usually do not support caribou (Addison, 1980). Figure 6 illustrates the abundance of arboreal lichens in forests of different types and ages of British Columbia and Alberta where this species occurs. In British Columbia, caribou utilized spruce-balsam stands 130 years of age or older (Freddy, 1974). Logging causes a reduction in the habitat of woodland caribou. In Saskatchewan, clearcutting of lichen-production jack pine and black spruce stands could be detrimental to this species for many years to come (Hunt and Phillips, 1978).

Effects of clearcutting being the disparition of lichens for many years, the removal of snags should increase this effect since they are old trees providing support for lichens. Also the removal of tops and branches should increase the negative effect as the short-term food supply is also removed. The living residues (tops and branches) can provide a major, though temporary, supply of

Figure 6. Abundance of arboreal lichens in forests of different types and ages.



* : Scotter (1964)
** : Edwards *et al.* (1960)
*** : Scotter (1964)
**** : Edwards *et al.* (1960).

Source: Bunnell and Eastman (1976).

Table 29. Interactions between forest biomass extraction and selected wildlife species of life forms 1.1 to 1.8: Description of potential effects and mitigative measures

Life form and species	Activity	Direct effects	Indirect effects	Mitigative measures
1.1 Woodland caribou	- Clearcut logging	- Loss of food and shelter (winter)	- Reduction of habitat - Reduction of population	- Selective or patch-clearcutting - Reservation of climax forest and buffer strips to permit migration to winter habitat - No logging on islands used by caribou to give birth to their fawns
	- Tops and branches removal	- Loss of temporary food supply	- Reduction of population	- Removal of tops and branches one or two years after logging
	- Logs removal	- Increase of ungulate movement	- Increase of forage accessibility	
	- Snag removal	- Disparance of foci of lichen	- Reduction of food and reduction of lichen colonization of second-growth forests	- Preservation of old lichen-bearing snags
Blue and Spruce Grouse	- Clearcut logging, snags and logs removal	- Destruction of nesting sites, loss of food and escape cover	- Reduction of population	- Selective or patch clearcutting
	- Season of operation	- Abandonment of nests - Destruction of nests by machinery	- Reduction of population	- No activity in the nesting period
Red-backed Vole Rock Vole	- Clearcut logging	- Loss of habitat (food, shelter, escape cover)	- Reduction of population - Reduction of food supply for larger carnivores (birds, mammals)	- Partial removal of residues to ensure food, shelter and escape cover
1.2 Grizzly	- Clearcut logging	- Reduction of food and loss of denning sites and escape cover - Raise of human conflict	- Reduction of population	- Preservation of large areas of untouched forest or limitation of human activities
Lynx, Fisher	- Clearcut logging - Residues removal	- Loss of preys (eg. squirrel) or tree cavity users and loss of denning sites	- Reduction of population	- Partial removal of residues
Rubber Boa	- Clearcut logging - Residues removal	- Diminution of preys (rodents) - Loss of cover and reproduction sites	- Reduction of population	
1.3 Douglas squirrel Red squirrel	- Clearcut logging - Snag removal - Logs removal - Tree-trunk removal	- Loss of habitat - Loss of food, shelter and reproduction sites	- Reduction of population	
1.4 American marten	- Clearcut logging - Snag removal	- Loss of an essential requirement for denning or food acquisition - Loss of dens and resting or escape covers	- Reduction of population	- Preservation of climax forests within the range of marten in Newfoundland - Restriction of human activities
Owls (Great Gray, Hawk, Long-Eared and Boreal)	- Clearcut logging - Snag removal - Logs removal - Season of operation	- Reduction of nesting sites availability - Increase of predation facility - When nesting, abandonment of nest	- Reduction of population - Short-term increase of population	- Protection of both critical nesting areas and key prey species from destruction and disturbance - Protection of old trees within critical areas - Small patch logging and partial residue removal - Enforcement of public education program to stress the value and vulnerability of birds
1.5 Eastern Chipmunk	- Clearcut logging	- Increase of food and reproduction sites	- Increase of mouse population	
White-footed mouse	- Residues removal	- Reduction of favourable feeding and reproduction sites and raise of predation pressure	- Reduction of population	- Partial removal of logs or residues from treated stands
	- Logging systems	- Increase soil compaction	- Reduction of population	
1.6 Grey fox	- Clearcut logging - Residues removal	- Loss of preys, cover and reproduction sites	- Reduction of population	
1.7 Gray squirrel	- Clearcut logging - Residues removal	- Reduction of shelter and food source - Increase vulnerability to predators	- Reduction of population	
1.8 Red-shouldered Hawk	- Clearcut logging - Season of operation	- Reduction of available nesting sites - When nesting, abandonment of nests	- Reduction of population	- Protection of both critical nesting areas and key prey species from destruction and disturbance - Enforcement of public education programs to stress the value and vulnerability of birds - Protection of old trees within critical areas

forage for wintering ungulates (Bunnel and Eastman, 1976). These authors also indicate that non living logging residues are generally beneficial to big game animals. So harvesting down woody material could have a positive effect on woodland caribou. Stevens and Storey (1977) stated that an area with no dead fall permitting entirely free movement gets the best rating for caribou.

Small mammals have been listed according to potential damage they could inflict on managed forests. They are also considered as primary consumers and so represent food supply to larger carnivorous mammals and birds. Any fluctuation of small mammals population can have an indirect effect on carnivorous species. Schultz (1973) indicated that all native small mammals are expected to adapt or thrive under forest management practices. Bunnel and Eastman (1976) consider that in British Columbia, only one mouse species - the red-backed vole - prefers or is restricted to mature forests. Clear-cutting old-growth forests would generate negative effects on this species.

Logging residues might generate unfavorable conditions for recolonization by small mammals. Although no study has treated this peculiar subject, the absence of residues can generate two direct effects: diminution of shelter against predators and lack of food (short term). Small mammals of this life form being essentially terrestrial, removal of snags would not produce any negative effects in the short term, but snags are the downed logs of the future. Logging downed woody material could influence small mammals population as this material is used for protection.

The character, density and distribution of logging debris may significantly affect both the number and species of vertebrate animals that use a site. Vertebrates use logs for a variety of reasons and in a variety of ways, the most obvious of which are for hiding cover and as sites for feeding and reproduction. Thus logs are considered to be more important as wildlife habitat than are other forms of woody debris (Thomas, 1979). The effect on small mammals will be more important if all residues are logged since Thomas (1979) stated that when logs are lacking, some windrows, slash piles, and root wads should be kept to simulate log habitats.

Restriction in small mammals numbers can be benefic for woodland managers. Cover provided by logs has been associated with animal damage to tree seedlings (Hooven, 1969; Mitchel, 1950) and dispersal of woody debris has been suggested as a mean of controlling problem rodents in some stands (Krauch, 1945).

On a short term basis, clearcutting will also have a negative effect on game birds of this life form. Huse (1965) indicated that unlike other species, game birds are not favoured by cutting in small or large blocks. Redfield *et al.* (1970) demonstrated that density of Blue Grouse very quickly increased from those in mature forests to a relatively even plateau that extends from 5 to 2C years after removal of the coniferous overstory. Once the coniferous cover becomes dense, grouse densities decline rapidly. Schultz (1973), stated that apart from destruction of individual nesting sites, which are normally not common in any event in dense coniferous stands, the timber harvesting operations will have no apparent impact on bird populations. Upland game birds thrive on a mixture of cutovers and heavier cover. Robinson (1958) stated that on Vancouver Island, in Douglas-fir belts, game populations soared after logging, Blue Grouse reaching a density of 1 pair per 3 acres. However, Addison (1980) stated that reservation of climax forest would serve to provide habitat for Blue Grouse. On a short term basis, clearcutting mature stands appears to be unfavourable to upland birds. It is foreseen that logging residues will increase the overall effect. Generally natural down trees are high enough off the ground that both Blue and Spruce Grouse nest under them. These birds also use logs for cover and food.

Dryade (1980) stated that in extracting forest biomass, the size of the area treated and the season are both important factors that can modify numbers and composition of avifauna. The season is important because disturbances during nesting season will result in the abandonment of the nest or physical destruction by machinery. Woody residues are also important for ground nesting birds.

Logging method is also an important source of impact since intensive machinery circulation on sites will particularly affect upland birds (Dryade, 1980). So, logging biomass in one operation might be less detrimental.

Carnivorous species associated with mature softwood forests are grouped in life form 1.2. They are directly sensitive to loss of cover and indirectly to loss of prey.

Schultz (1973) stated that Grizzly bears, by the combination of shyness to human encroachment and preference for undisturbed timber habitats, will be affected by timber operations. The ministry of Environment of British Columbia considers that logging operations throughout the province will have an adverse impact on Grizzly bear habitats and on the bears directly. Macey (COSEWIC, 1979) indicated that grizzly habitat is not a critical limiting factor. The important requirement is the availability of natural food and suitable denning sites. Cover may be an additional requirement. Biomass harvesting can provoke a modification of food (vegetation and mammals) and loss of cover would make bears more accessible to hunters.

Fisher may also be in conflict with the Complete Forest Concept. Large scale clearcut logging adversely affects this species (B.C. Min. of Env., 1980). Although small mammals associated specifically with mature softwood stands are highly affected by clearcutting, rodents characteristics of other habitats could colonize disturbed sites. However, this colonization could be restrained by lack of cover if residues are also logged. Indirectly, it is possible that fisher could be detrimentaly affected. Schultz (1973) indicated that the three small mammals likely to be adversely affected by local heavy cutting are the squirrel, which relies on mature conifer seeds and habitat, and the marten and fisher, which prey upon squirrels to a considerable degree, although the fisher is less of a climber, than the marten and feed mainly on the ground (Banfield, 1974).

Logging residues will also produce an effect on fisher. Firstly, removal of snags will contribute to reduction of the quantity of prey available since squirrels utilize cavities of old dead standing trees. Banfield (1974) stated that this species travels preferably on wind fallen trees. They live in logs or hollow trees. Logging this type of residue could thus produce a negative effect. Lynx occur mainly in the north of the commercial forest belt. It can be found in or near the dense under cover of thickets, never too far from adequate cover. Although less dependant of mature softwood stands, effects of complete biomass harvesting would be similar than for fisher.

There is little information available for reptiles and amphibians. It is so difficult to evaluate interactions related to the Complete Forest Concept. It could be predicted that a reduction of rodents population can affect this species. Logging residues and more specifically down woody material (logs) will affect reptiles inhabiting these sites. Animals such as the Rubber Boa not only feed around and under these logs but also inside them (Thomas, 1979). Thomas (1979) further indicated that some reptiles begin to use interiors of logs in mature forest as a reproduction site. Thus logs becomes cover for this reptile.

Wildlife associated with mature softwood stands which more specifically reproduce and/or feed in trees or shrubs (life forms 1.3 and 1.4) will probably be highly influenced by complete removal of biomass. As expressed by Schultz (1973), serious or permanent adverse effects are unlikely. Squirrels use burrows under stumps and tree trunks, and cavities in hollow trees for winter habitat. In the summer, they may use leafy nests built at the top of trees (Cowan and Guiget, 1956; Banfield, 1974).

Except squirrel, all species classified under these life forms are rare, threatened or endangered. Complete forest biomass extraction will generate important long term effects on these species. American marten, for instance, have been studied by many authors. Krasooskij (1970) stated that in the closely related Pine marten, populations increase with increase in the population of small mammals associated with large scale clearfelling. Vaisfel'd (1972) however noted no increase of population following an increase of small mammals.

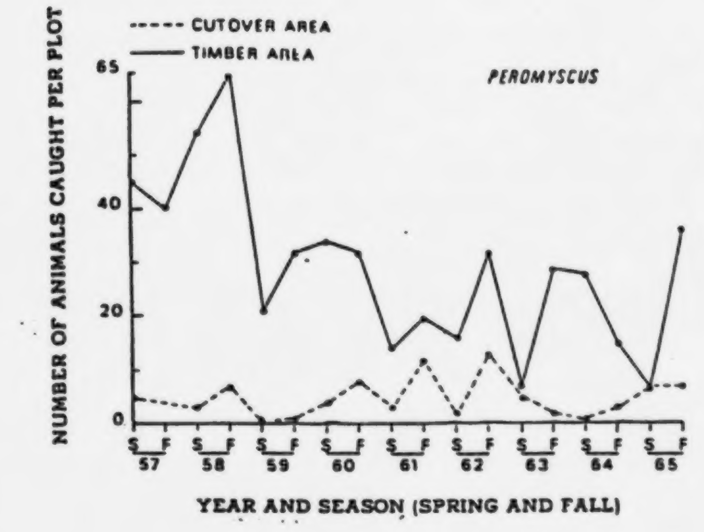
Within the Complete Forest Concept, it is not ensured that rodent population will increase as stated by many authors. In fact, this rise of population being related to available food and shelter a more drastic effect could be predicted for marten. Skinner (1979) has stressed that for the Newfoundland marten, forest exploitation must result in the loss of an essential requirement for denning or food acquisition especially where clear-cutting is practised. Considered as an arboreal species (Banfield, 1974), marten is a typical snags user. Snags are used as dens or as nesting for escape cover. Many specialists see a direct relationship between the number of snags and the number of snag-dependant wildlife in forest (Thomas et al., 1974; Beebe, 1974; Jackman, 1974; Pozmanin, 1956; Bruns, 1960; Franz, 1961; Herberg, 1965; Haapanen, 1965 and Gysel, 1961). Marten is a secondary cavity user of snags. A primary cavity excavator, such as the woodpecker, must first dig a hole. Removal of snags affects marten directly, since it lost the dens cavities indirectly by the loss of primary cavity excavations. The removal of downed woody material might amplify the loss of forest cover on a short term basis as this will facilitate predation on small mammals.

Avian predators of these life forms will also be affected. Clearcutting reduces nesting site availability. The Long-eared Owl, for instance, generally uses old nests of crows, hawks, squirrels and occasionnally tree cavities and tops of broken stubs (Harrison, 1975). The Great gray Owl also nests in trees and availability of nests, again is probably the most important limiting factor. Land clearing removes large blocks of habitat and has adversely affected this species (Nero, 1979).

Method and season of operations could have a more severe effect on birds of this life form. Dryade (1980) indicated that clear-cutting operations in the nesting period can be highly detrimental. Removing downed woody material would not however affect nesting sites of these raptors, since they are not ground nesting species. On a very short term, logging residues might facilitate predation.

Few species have been considered to inhabit specifically mature hardwood forests exclusively. Species classified under life forms 1.5 to 1.8 are considered as potential pests. Banfield (1974) stated that hardwood forests are preferred habitats of Eastern chipmunk and the White-footed mouse. Many studies explain the effect of cuttings on small mammals population. Gashwiler (1970) noticed an important increase of mouse population after clearcutting. Tevis (1956) did not notice a significant increase three months after cuttings but did notice an increase three years after; the increase of population is related to the increased diversity of vegetation. Harris (1968) noted that mice (*Peromyscus*) were more numerous in timber than in cutover areas (figure 7). Krull (1970) whose study included Eastern chipmunk did not notice significant population rise after clearcutting. It could be supposed that cutting has a minor and probably beneficial effect on small mammals populations (Dryade, 1980). However, removal of tops, branches and downed woody material could generate greater effects for this life form. Availability of favourable cover, feeding and reproduction sites will be diminished and predator pressure will increase. Since these species are

Figure 7. Quantity of mice (Peromyscus) captured within three nights on cutover and timber area.



considered to be potential pests, this interaction could be beneficial to forest managers.

Logging systems can produce variable negative effects along with frequency and intensity of traffic on cutover areas. So, harvesting in two or more operations can increase soil compaction and diminish accessibility for small mammals living in the upper soil layer (Dryade, 1980). Furthermore, higher soil compaction can cause regeneration problems which might affect the overall availability of nutrients.

The single species classified under life form 1.6 is the Grey fox. This species utilizes a variety of habitats throughout its range such as chaparral, swamps and deciduous forests (Banfield, 1974; Cahalene, 1961 and Peterson, 1966). Although in southern Ontario, it is known to prefer deciduous woods, Grey foxes are not as adaptable to human activity as are mammals of other life forms of more open habitats such as coyote or red fox. Competitions from red foxes could also limit grey fox populations (Steers, COSEWIC, 1978). It could be stated that this life form might react similarly than life form 1.2: loss of cover, loss of preys and on short term a greater prey accessibility.

Life form 1.7 contains one arboreal species of mature hardwood forests, the Grey squirrel. It utilizes two types of residence: a permanent residence located usually in a hollow tree or a woodpecker hole and a summer residence made of leaves and twigs at 10 to 15 m from the ground (Banfield, 1974). Consequently removal of forest cover will reduce shelter and food source (seeds, buds,...) and also increase its vulnerability to predators such as weasels, foxes, lynx and raptors (Banfield, 1974). Removal of snags, logs, tops and branches could contribute to increase the overall effects.

The Red-shouldered Hawk of life form 1.8 can similarly be affected by clear-cutting as it reduces availability of nesting sites.

Large clearcutting would so be very detrimental. Although nests are built without regard for the kind of trees, it is often close to the tree trunk, usually 6 to 18 m from the ground (Harrison, 1975). Small or patchy clearcutting might, however, create positive effects since the bird hunts in open terrains. Removal of residues and snags can lessen the positive effects. In fact the loss of residues will contribute to reduce the amount of prey. Human activity while nesting could also be detrimental.

It can be stated that all species that could be added to these forest types would react the same as for those hardwood or softwood life forms along with specific species requirements.

Life form 2.1 comprises many game species ranging from large ungulates to grouse and chipmunk. Although they are encountered in other habitats, they are more numerous in immature forests and marginal farmland where more food is available.

Ungulates (moose, deer, elk,...) have been the subject of many studies to determine proper food and shelter. Black *et al.* (1976) considered cover (both hiding and thermal), forage and water as the components necessary to make an area suitable for big game habitat. In general, logging and opening the forests tend to increase population of big game (Huestis, 1956). Logging causes reversion of extensive areas to young stands (table 30) often composed of plant communities characteristics of stage of secondary succession (Telfer, 1974). These young stands are comparable to life form 2.1. However, very large cut areas are not much used by moose until a new stand becomes well established (Telfer, 1974). This author stated that much of the effects on wildlife from logging depends in the pattern produced (including size and shape of cut areas, location and species composition of uncut stands). Clearcutting reduced the sheltering capabilities of the stands to such an extent that the logged areas provided almost no thermal cover and only poor hiding cover (Hunt and Phillips, 1978). Winter severity is thought to be a major limiting factor

Table 30. Interactions between forest biomass extraction and selected wildlife species of life forms 2.1 to 2.8: Description of potential effects and mitigative measures

Life form and species	Activity	Direct effects	Indirect effects	Mitigative measures
2.1 American moose, White-tailed deer, Black-tailed deer Mule deer, Elk	- Clearcut (greater than 200 ha)	- Reversion of extensive areas to young stands - Reduction of sheltering capability and lack of thermal and hiding covers - Reduction of snow interception	- Increase forage for ungulates - Avoidance of large central areas where too exposed and too far from cover - Reduction of game movements	- 50% removal pattern ground rule and 4,5 to 6 m regeneration before cutting the remaining blocks - Limit clearcut size to approximately 100 ha - Reserve part of the forests for winter thermal and hiding covers - Reduction of cut-block width (less than 200 m) - Strip clearcutting of varying widths, with alternate uncut strips of the same widths
	- Removal of tops and branches - Removal of unmerchantable trees and shrubs	- Loss of temporary food supply - Reduction of diversity (tree species, height) - Increase forage accessibility - Reduction of sheltering capability of cutovers	- Increase winter mortality - Unsuitable habitat for ungulates - Increase big game movements - Reduction of ungulates activity	- Cutting operation in two steps: 1. logging valuable stems at fall 2. residues one or two years after - Partial removal of residues and of unmerchantable trees and shrubs
	- Harassment and noise	- Exposure of animals to new alarming stimuli - Avoidance reaction	- Alter behavioral pattern and displacement of animals	- Reduction of cut block width (120 to 160 m) - Maintenance of minimum 100 m buffers between blocks. Smaller cutblocks (approximately 30 ha) in high harassment areas
Ruffed Grouse California quail Bobwhite	- Clearcut (greater than 200 ha) - Removal of logs and stumps	- Loss of habitat - Reduction of nest sites	- Reduction of population	- Apply recommendations for ungulates
2.2 Red fox, Coyote, Least weasel, Long-tailed weasel,	- Clearcut (greater than 200 ha) - Removal of residues	- Decrease of prey species - Increase of predator pressure - Loss of denning sites	- Reduction of population	- Apply recommendations for ungulates (except harassment)
Peregrine Falcon	- Clearcutting (less than 200 ha) - Removal of residues - Human presence	- Suitable openings for hunting - Increase hunting pressure - Nest sites desertion - Nest sites destruction	- Reduction of key prey populations - Reduction of population	- Protection of individual birds and their breeding habitats
Kirtland's Warbler	- Fire control	- Reduction of the size of individual burns	- Loss of habitat (young jack pine stands)	- Protection of suitable habitat within actual range
2.3 Vancouver Island Marmot	- Human presence	- Disturbance and alteration of behavioural pattern	- Reduction of population	- Keeping intact buffer strips around known critical habitats
2.4 Short-eared Owl Burrowing Owl, Golden Eagle, Prairie Falcon, Swainson's Hawk, Ferriguneous Hawk	- Biomass extraction	- Increase of human presence and associated noise	- Disruption of breeding activities	- Census of population and location of nest sites before any developments
2.5 - 2.6 Deer mouse, Snow-shoe hare, Porcupine	- Clearcutting (greater than 200 ha)	- Unfavourable	- Reduction of population - Reduction of preys for mammals, birds and reptiles	- Limit clearcut size and width
	- Residues removal	- Reduction of escape, hiding and thermal covers for small mammals	- Raise of predation pressure - Reduction of population - Decrease of animal damage to future crop	- Partial removal of residues
Ermine, Bobcat, Eastern Cougar, Western Mountain Lion, Striped Skunk, Wolf, Black Bear	- Biomass extraction	- Reduction of preys - Harassment and disturbance conflicts	- Reduction of population	- Protection of denning sites when observed
2.8 Raccoon, Richardson's Pigeon, Hawk	- Residues removal	- Loss of nesting and denning sites	- Negligeable considering the high adaptability (raccoon)	

for ungulate population in the north temperate latitude with adequate food and cover of prime importance in mitigating the effects of the winter weather (Hunt and Phillips, 1978). Similarly, the Environment Council of Alberta (1979) indicated that if cutblocks are too large, the animals will avoid using the large central areas where they are too exposed and far from cover. Stelfox (1962) stated that during the first five years after logging, moose used the cutover area only as travel lanes and elk as summer browse, whereas deer foraged continuously.

Logging activities resulting in changes in plant species and age composition are generally beneficial for moose. However, most moose activity in cutover areas is within 100 m of protective cover in spruce (Hamilton and Drysdale, 1974) or 320 m in aspen (McLennen, 1974).

Bunnel (1978) stated that of the forest-dwelling ungulates, moose should be the least dependant upon forest cover to meliorate impacts of deep snow. Kelsall and Telfer (1974) concluded that snow was probably the most important factor limiting the expansion of moose populations beyond their present range. Forested sites provide also a more favourable environment in terms of heat exchange (Bunnel, 1978). In high snowfall areas, cover and snow interception become more important that the physical presence of browse (Jones, 1974).

Deers are animals of early successionnal forest, deciduous and shrub growth (Cowan, 1952). Three sub-species are considered in this 2.1 life form: white-tailed deer, black-tailed deer and mule deer. The effects of clearcutting on deer appears to be similar to that on moose. Cutting small blocks is particularly favourable for deer (Lyon, 1966). On a very short term, they are favoured by browses present in forest residues (Gates, 1969). In Douglas Fir stands logging, particularly clear felling increased populations of deer (Hooven, 1970; Robinson, 1958; Smith 1968). Strip clearcutting (60 m) in spruce - fir stands doubled the use by mule deer

10 years after logging (Wallmo, 1968). However, deer are more vulnerable than moose to snow depth. Clearly, snow cover is a critical factor influencing North American deer. Bunnell (1978), Pearson (1968) and Wallmo (1969) found that deer used the interface between forest and open areas intensively, but did not venture far from the forest cover. Deer appear to require mature or at least closed, coniferous forest in regions receiving snowpack of 60 cm of greater. In Québec, forest stands mostly used as winter range by deers show the following characteristics (Pichette, 1980): 75 to 85% of coniferous trees, basal area of 25 to 30 m^2/ha and a minimum age of 30 to 40 years. Telfer (1978) considered an average of 35 m^2/ha as the minimal basal area for shelter. Tomm (1978) stated that deers have a strong preference for cutblock peripheries while use declined sharply at 100 m from cover and was marginal beyond 120 m. The logging practice of large clearcut areas is definitely detrimental to populations in areas which are subject to heavy snowfall (Edwards, 1956, Hebert, 1978).

The high fidelity of white-tailed deer to their home range is well known. Animals will return to the same winter range each year, even if food is lacking (Huot, 1973; Verme, 1973; Telfer, 1978). Any important alteration of forest cover in traditionnal winter range will be detrimental to deers.

In Québec, although an excessive animal harvest in the sixties and severe winters of the seventies have considerably reduced populations of white-tailed deer, Potvin (1977) noted a general deterioration of winter habitat. This deterioration is due to an increase in clearcut size and a decrease of partial clearcut. This author indicated that deer browse only in the part of clearcut adjacent to cover. If further movement is required, the energetic value of food ingested would be lower than the energy required to move in the snow.

In Manitoba, with the onset of forest clearing, a substantial amount of forest edge habitat favourable to the white-tailed deer was created. The mule deer was forced into more inaccessible areas. Eventually the population dropped (Shoesmith, 1976).

In Colorado, Wallmo (1969) stated that clearcutting lodgepole pine and spruce - fir forest in strips of varying widths, with alternate uncut strips of the same widths, doubled the use by mule deer 10 years after logging.

Elk have a propensity to inhabit forest fringe habitat (Hunt, 1981). The limiting factors related to winter weather are the same for this species as for other ungulates. Clearcutting severely reduces the sheltering capacity of an area for a significant interval after logging. After logging, herbs and shrubs increase, providing a much greater supply of forage, particularly during the green period of the year when winter snow depths and exposure to chilling winds do not restrict utilization of the clearcuts by big game (Hunt and Phillips, 1978). In Saskatchewan, Hunt indicated that densities of elk was 174% higher in the cut portions than in the uncut parts of the survey blocks. He also noted that snow depths in and around the cutover blocks during the study period were not sufficient to be important to elk. Elk should be significantly more limited by snow than are moose, and under the same conditions, less than are deer. Use of clearcuts has been reported to be heavy in December - January and May - June, but severe conditions of 90 to 120 cm of crusted snow caused elk to utilize the more timbered areas of the winter range during February to April (Baglien and Biggins, 1976).

The effect of active logging on elk has been studied but in other seasons than winter. Bailey (1966) showed that logging methods which leave a mosaic of intermingled disturbed and undisturbed areas create a habitat beneficial to elk. Peak utilization by elk occurred at cutblock edges. Decline in elk utilization with increasing distance from cover was pronounced at 80 - 100 m.

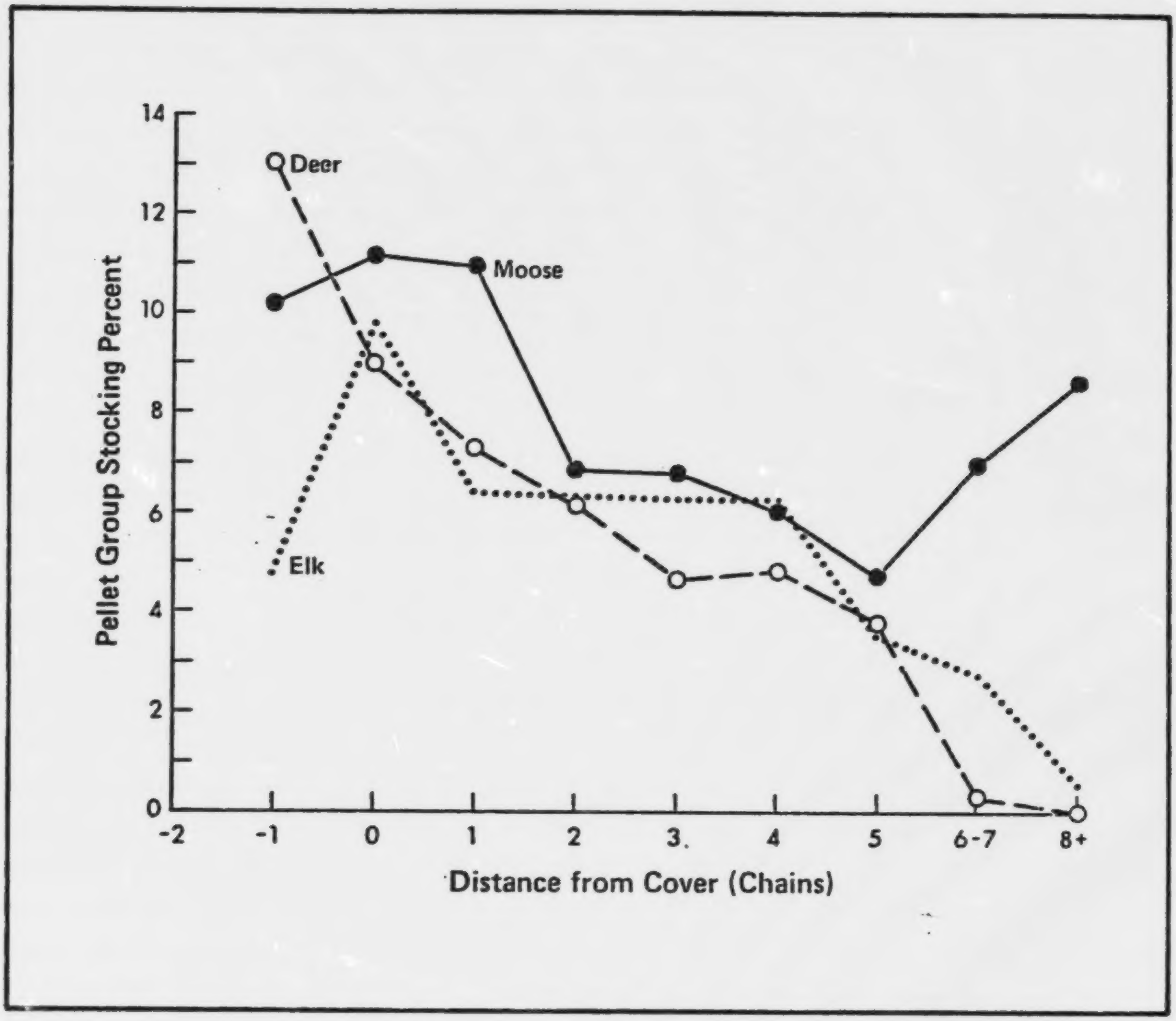
Optimal cutblock widths are 160 - 200 m (Tomm, 1978). Black, Scherzinger and Thomas (1976) outlined specific cover requirements for elk. For this species, security cover was defined as vegetation capable of hiding 90% of an animal at a distance of 60 m or less. However, elks are typified as grazers and require open forage areas to accomodate habitat use behaviour (Stevens, 1974). Edgerton (1972) also observed the preference of elk for clearcuts over partial cuts.

This literature review demonstrates that large clearcuts are generally detrimental to ungulates in short terms since they actively use only the forest edge for food. Distance between forest cover and food zone differ according to species (figure 8), moose being undoubtfully the species which moves furthest. This negative effect is especially high in winter when ungulates use forest cover (mainly softwoods) for protection against heavy snow accumulation and chilling winds. Although on a medium term, clearcut increases food availability, loss of shelter or loss of energy while travelling and feeding in the exposed clearcuts prevent utilization of the addition forage until regrowth of trees has been sufficient to provide shelter patches.

Conversely, strip and patch clearcutting will generate positive effects since they produce a large amount of forage and permit the animal to stay close to forest cover.

Few authors discuss the immediate effects of forest harvesting. It is however known that, for instance, season of operations is important. Villeneuve and Brunet (1979) indicated that logging operations should be done at fall so that tops and branches lying on the ground will furnish supplementary food. Reynolds (1966) stated that deer prefer sites where logging residues are left on the forest floor. Hooven (1973) concluded that effects of clearcutting are, in this case, positive but on a short term only. Beall (1973) noted that after approximately three weeks of logging activity, a gradual shift back to normal use patterns was noted.

Figure 8. Moose, deer and elk activity over distance from cover. The graph represents combined plot data and differences in use curves by species are highly significant (p < 0,01).



Source: Tomm (1978).

Living residues can thus provide a major though temporary supply of forage for wintering ungulates (Bunnel and Eastman, 1976). Harestad (1975) observed that black-tailed deer in Coastal Douglas-fir utilizes small patches (less than 1 ha) of residual conifers in clearcuts as shelter giving them access to forage that is otherwise less available. However, Bunnell and Eastman (1976) stated that slash accumulations would have adverse impacts on many wildlife species by reducing forage accessibility. This problem will be most acute for ungulates. Therefore, logging residues could turn out to be beneficial giving better accessibility to summer forage. Conversely, tops and branches removal will contribute to eliminate temporary food supply in winter.

Harvesting non living residues can increase big game movement. Piled slash around clearcut areas is a known method for impeding ungulate browsing on planted trees by ungulates (Bunnell and Eastman, 1976). Dimock (1974) Garrison and Smith (1974) and Pierovich et al. (1975) indicated that continuous concentrations of slash should be avoided, because they restrict the travel of big game animals on frequently used trails.

Harvesting unmerchantable trees and shrubs could produce detrimental effects on short, middle and long terms. Hunt and Phillips (1978) stated that the only shelter in clearcuts was in the form of the shrubs remaining after logging although for the most part the shrub strata in the prelogging stands had been poorly developped. Harvesting shrubs would considerably diminish the use of logged areas by ungulates. Woody browses constitute most of the diet of moose, elk and deer during the non-green period of the year. On short term, the loss of forage will constitute a sterile habitat for ungulates. On middle term, the net result would be reduced diversity in tree species during the next rotation and less variation in heights of trees and tree clumps within the stand (Telfer, 1978). Large homogeneous areas are generally unsuitable as habitat for ungulates (Tomm, 1978). Some ungulates will be less affected by the removal of shrubs mainly in summertime. So deer show less preference for herbs than do elk. Beneficial effects will be through the initiation of early seral stages that contain important foods for some species. Swanson (1970) found significantly higher elk use on moderate or heavily disturbed sites than on lightly disturbed sites.

Logging systems and methods do not appear to interact strongly with ungulates. Some authors have analyzed the effects. Bunnell and Eastman (1976) indicated that deep disturbances associated with tractor logging can lead to severe erosion and adversely affect wildlife through loss of habitat and lowered site productivity. These authors assert that logging in summer results in greater disturbance than logging in winter when the ground is frozen and shielded by a protective snow layer. Furthermore, these authors stated that extracting methods can induce a more or less removal of slash which can be advantageous (short term) for ungulates. Table 31 indicates, for instance, that helicopter logging leaves the greatest amount of slash while the high lead and tractor systems will leave a lesser amount. In our conceptual model, full-tree logging system has a high proportion of branch material lost due to breakage in skidding (up to 50%) (Weldwood, 1979). That author also indicated that in harvesting of branch wood and transport to mill, breakage losses are considerable.

Noise can also disturb ungulates. For instance, avoidance reactions within 0,8 - 6,4 km from disturbance were recorded by many authors (Ward, 1976; Lyon, 1972; Ream and Marcum, 1975; Beall, 1976). But Beall (1976) reported seeing a group of six elks feeding within 100 m of a skidding operation. That observation suggests that under certain circumstances elk will become habituated to disturbance.

Harassment involves the exposure of animals to new and usually alarming stimuli (Hudson, 1975). The consequences are many, and include altered behavioral patterns and displacement of animals (Stelfox and Taber, 1969). Responses seem however different with

Table 31. Soil disturbance and slash accumulations resulting from different types of logging in western North America (derived from Bockheim et al., 1975)

Type of logging	Type of disturbance[1]					Mineral soil exposed[1]	Amount of slash[1]
	Forest floor	Shallow	Deep	Compacted	Total		
Horse (1)[2]	-	10	2	-	12	12	17
Jammer (1)	-	13	2	-	15	15	30
Tractor (1, 2, 3, 5)	6	13	25	7	50	37	15
High-lead (2, 3, 4, 5)	9	11	6	2	32	20	14
Skyline (4)	-	-	-	-	-	-	23
Helicopter (5)	31	2	3	-	36	5	45

[1] as percentage of an area

[2] parentheses enclose source of data:

(1) : Garrison and Rummell (1951 (2) : Wooldridge (1960)
(3) : Dyrness (1965) (4) : Ruth (1967)
(5) : Bockheim et al. (1975)

Number of areas examined for horse = 2; jammer = 3; tractor = 22; high-lead = 19; skyline = 4; helicopter = 1

Source: Bunnell and Eastman (1976).

species. Deer display the plasticity in behavior that permit learned and adaptative responses to occur quite quickly (Tomm, 1978). Response mechanisms of moose to environmental stimuli appear to be relatively fixed or automatic, and lack the degree of behavioral plasticity expressed by deer (Prescott, 1974). Elk tend to deal with harassement by avoidance mechanisms. Lyon (1975) for exemple, noted 3,2 km of undisturbed timber or a topographic barrier was required to achieve security from logging activities.

Some game birds are also part of this life form (2.1). There is little available information on the effects of clearcutting on game birds. The favourable influence of cutting to ungulates is not found for game birds (Huse, 1965). Hagar (1960) is discordant with this opinion since he stated that logging in Douglas-fir results in an increase in the population of birds. Diggle and Addison (1977) stated that the diversity of habitat created by intensified forest management combined with deer habitat management will favour a very substantial increase in Ruffed Grouse populations. He also stated that ideal habitat for grouse would consist of a mosaic of different age classes of timber, with natural openings and restocking cutovers. Pomerleau (1974) also indicated that all human intervention aiming to maintain appropriate retreats and to create fertile zone for food should favour productivity of Ruffed Grouse. Schultz (1973) added that the prevention of large fires and their replacement with a mosaic of different cover types will benefit birdlife. Finally Godfrey (1967) stated that the Ruffed Grouse make heavy use of young second-growth hardwood forest, on the edge of forest and meadows.

In general, forest cuttings seems beneficial to upland birds. As some authors indicated that well-planned forest management that included provision for ungulate habitats would also partly favour upland birds, it can be concluded that large size clearcutting will be unfavourable, whereas group or strip cut would increase populations. Halls (undated) indicated however that season of operation is an important limiting factor. Forest operations in fall or winter would be less prejudicial than in spring or summer time while nesting and resting occur.

In our conceptual model, logging residues might be detrimental as birds of this life form are ground nesters requiring shrub strata for protection or at least some downed woody materials. Harrison (1975) stated that the Ruffed Grouse nests in thickets and dense cover, the female hollows a site for her nest at the base of a tree, under log, root, in dense brush, or under an intact log (Thomas, 1979). Food for grouse comprises leaves, seeds, berries and fruits (Pomerleau, 1974). Important fluctuation of population is predicted for these birds if all biomass is harvested from sites. Furthermore, on a short term, we can imagine a more important predation on these birds as cover will be more restricted.

Life form 2.2 comprises carnivorous (or insectivorous) species preferring disturbed or second-growth forests and frequently associated with forest edges. Some are classified as fur bearers (fox, coyote,...) others are considered as threatened or endangered (Peregrine falcon,...).

Density of populations of mammals of this life form are closely related to the abundance of prey. Coyotes, for instance, prefer and use any habitat that has an abundance of prey species (B.C. Min. of Environment, 1980). Richens and Hugie (1974) concluded that there is no barrier to coyote expansion in areas where adequate food is available. Logged areas which provide abundant edge for a variety of prey species (small rodents, birds, occasionnally adult deer) are utilized by the coyote (Hitton, 1978). The coyote is highly adaptable and adjusts well to human activities. The fox has also been successfully adapted to logged-over forests.

Mustelids prey on small mammals and terrestrial species of this life form, eat small mammals and birds. Most mustelids have definite dens or nesting sites which are usually burrows taken over from other animals. Dens may also be in hollow trees, brush piles or in the roots of trees (B.C. Min. of Environment (Mustelid), 1980).

There is little information relating forest operations to these animals. Although no information permits the evaluation of the effect of large and small clearcuttings, it can be predicted that any cutting method favouring prey such as small mammals, Ruffed Grouse, hare, deer,... will favour these animals. Also, as they favour openings within the forest, the loss of a part of forest cover can only be beneficial.

It can also be predicted that residues removal might facilitate either predation on small mammals or being captured by larger predators. The loss of stumps, roots and downed woody material can also diminish available denning sites.

The only predictable interaction between logging methods and animals of this life form is that if the method leaves residues on the ground the animals will increase due to increases in prey species and also because more den sites will be available.

Birds associated to this life form (Peregrine falcon, Kirtland's warbler) are well known and represent vulnerable species to which treats are well documented. Schultz (1973) indicated that falcons breed slowly and are vulnerable to disruption of nesting sites by cutting. Peregrine falcon, as other birds, require three specific conditions for breeding: nest sites, nesting territory and hunting areas. Usually peregrines hunt their prey in the air, the open space above or around the hunting area is important. Forest operations could create suitable openings for hunting. This positive effect is however strongly counteracted by human disturbance, nest destruction and a reduction of preys.

Human intrusion at or near nest sites has often been sufficient to cause breeding interruptions and nest site disertion (Hickey, 1942). Campbell and Davies (1973) indicated that peregrines appear to react strongly to helicopters. Logging and skidding machinery used for biomass extraction could undoubtfully generate similar effects in areas where the bird is present. Dryade (1980) indicated that removal of trees and shrubs and logging residues will most particularly affect avifauna. Indirectly, it could be said that same prejudicial effects will affect Peregrine Falcon (reduction of preys). Finally, the precarious position of the sub-species «anatum» across Canada permits suggestion that any perturbation in northern areas that changes both the quantity and quality of breeding habitats will be detrimental.

The Kirtland's Warbler is one of the world's most critically endangered birds. This bird is specialized in its habitat. It prefers even-aged jack pine stands between 2 to 6 m high. Pines must have living branches to the ground. Formerly, the extensive fires in the pinelands created new breeding habitats as the older, less suitable jack pine was burned and the seeds were released to regenerate the area to pine growth. Fire control operations have reduced total acreage and size of individual burns. Forest management practices encourage the conversion of jack pine to red pine or hardwood (Byelich, 1976). Forest management can however regenerate suitable habitat for this vulnerable warbler. Clear-cutting, burning, planting and seed tree cutting are being used to create the desired habitat by leaving approximately 25% of each block in small openings (Capen, 1979).

Life form 2.3 is characterized by species that are not inhabiting specifically forests. They are mainly encountered in meadows and cultivated fields. They could be classified under small mammals (vole, rabbit,...), upland birds (partridge, pheasant) or vulnerable species (bison,...).

Although the Complete Forest Concept will not be undertaken in these areas, some species can be indirectly influenced by human disturbance associated with forest operations. This is particularly the case of the Vancouver Island marmot which inhabits alpine and subalpine areas with steep slopes, talus debris and open meadows. Such habitats are located on the higher mountains of Vancouver Island. Munro (COSEWIC, 1978) stated that logging adjacent to some habitats may have rendered them unsuitable for marmots although this has not been proven. The most important disturbing agents are wanton killing or excessive disturbance through development by man.

Another threatened species of this life form is the wood bison. The summer range of this mammal comprises the upland prairies, open forest and sand ridges. Grasses and other forbs constitute the main food source. At present, known herds of wood bison are increasing in numbers. Biomass harvesting would not actually affect this species since the animals are confined within national parks or occur in northern areas where forest exploitation is unlikely. However, the 1978 reintroduction trial of wood bison in Jasper National Park showed that animals will leave a reintroduction site and move outside of the parks limits. Future occurrences of this kind might place wood bison in areas where they would intereact with forest biomass extraction.

Life forms 2.4 comprises carnivorous, rare, threatened and endangered species confined to prairies (American badger, Burrowing Owl, Snakes,...). These species, as the previous life form, will not be directly affected by forest operations. For example, most habitat of Burrowing Owl is found in open country. In British Columbia, the limiting factors of this species is the lack of nest burrows due to the virtual disappearance of the badger, badger being limited partly by human disturbance. Greater accessibility consequent to more intensive harvesting could generate negative effects on these related species, although openings created by logging operations could be advantageous.

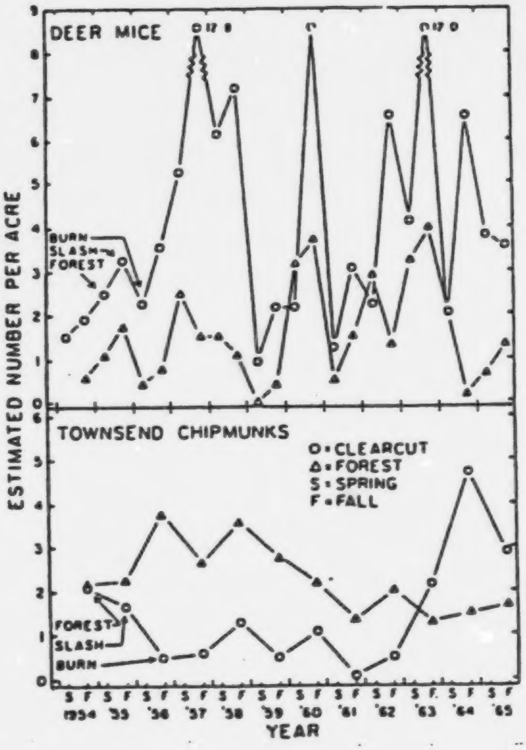
Raptors such as the Golden Eagle, Prairie Falcon and the Swainson's hawk have been depleted by insecticides such as D.D.T.. Loss of habitat did not appear as being a limiting factor. These birds are also sensitive to human disturbance, while nesting. Any work undertaken within the home range of these species could be detrimental in the nesting period.

There is little information available on reptiles although a factor reducing populations is human harassment. This particular behaviour is more significant for snakes.

Some species within the life forms 2.5 and 2.6 possess a high adaptation capacity to habitat manipulation. Most of the mammals are considered as potential pests (deer mouse, snowshoe hare, porcupine, black bear) while others are rare or endangered (Eastern cougar, Western mountain lion, Eastern box turtle, Eastern Milk Snake, Black Rat Snake,...). Herbivores of life form 2.5 are stated in many studies. Krassoskij (1970) indicated that cutting in small blocks is more favourable for small mammals than cutting large ones. In Douglas-Fir stands, populations of small mammals increased very rapidly after logging (Spencer, 1956). Tevis (1956) found that clear felling in Douglas-Fir stands in N.W. California increased by 8 species of mammals and decreased by 4, with deer mouse increasing the most. James (1956) found that clear felling in Sitka spruce stands results in high mouse population. Gashwiler (1970) also noted a significant increase of deer mouse after felling (figure 9).

However, Harris (1968) in a study on mice has found that populations have remained six times higher in forest than on clearcut stands.

Figure 9. Changes of population of deer mice and Townsend chipmunk after clearcutting.



Source: Gashwiler (1970).

Showshoe hares make intensive use of clearcut areas after a dense stand of evergreen saplings develops to provide escape cover (Telfer, 1974).

There is little information relating clear felling and porcupines. This species is well known as damaging trees 15 cm or less in diameter (Banfield, 1974).

Although there are few negative effects of conventionnal clear felling on these animals, removal of residues will be unfavourable. Logs provide sufficient shelter for these small animals when they are well distributed over the ground (Winn, 1976). Areas of crisscrossed, windthrown timber can be used by porcupines (Taylor, 1935). Logs are also offering hiding and thermal cover for showshoe hares (Winn, 1976).

Considering that these species are potential pests and can create damage to managed forests, it can be concluded that forest biomass harvesting will have a positive effect for managers since it probably will diminish population. Dimock (1974) indicated that wildlife habitats can be manipulated by varying the method and intensity of timber harvest and the techniques used for slash disposal. Krauch (1945) suggested disposal of woody debris as a mean of controlling «problem» rodents in some stands.

Not much can be said about the Eastern cougar. As Novak (1974) attributed the decline of the species in eastern North America to persecution by man, it can be said that forestry activities will generate an increased human pressure in areas where present.

The Western mountain lion is not an endangered species. As it preys on ungulates and small mammals and also on domestic animals, it is generally killed in areas of human activity. In British Columbia, forest activities are not considered as a limiting factor. Any management activity that will increase deer, beaver, elk, moose, goat, rabbits, birds and smaller wildlife will favour this species (Cowan and Guiguet, 1973). Same observations can be applied to wolf in western provinces.

As much is yet unknown about the critical habitats of reptilian species in Canada, not much can be said. Overall, as these species are carnivorous, they are contributing to reduce rodents population which can be helpful to forest managers.

The American black bear, an extremely adaptable animal, can tolerate some habitat alterations or disturbances if there is enough cover and food available. An important interaction with forest biomass harvesting will be an increased probability of human conflicts which often leads to reduce populations. Removal of residues may reduce food for bears by removing habitat for ants and other organisms of rooting wood. Elimination of the shrub stratum in forests would also limit areas of berry production which is very important for bears.

Raccoon and Richardson's Pigeon Hawk are the two carnivorous species of various habitats reproducing in trees, snags or bushes (life form 2.8). Raccoons are quite adaptable to most of the changes in the habitat caused by man (B.C. Min. of Env., 1980). They live in deciduous and coniferous forests and shrubbery, usually near water. The den is usually a hollow tree, stump, cave or burrow excavated by other mammals. As raccoons are trapped for their fur, logging snags, old trees, stumps will contribute to population reduction. However, considering its high adaptability, the effect should be minimal on the overall population. This species may also conflict with man as it often uses drain pipes, culverts, barns and barrels for shelter (Banfield, 1974).

INTERACTIONS BETWEEN FOREST BIOMASS EXTRACTION ACTIVITIES AND TERRESTRIAL - AQUATIC LIFE FORMS (3.1 TO 3.5)

Mammals related to life form 3.1 are semi-aquatic (beaver, muskrat). Banfield (1974) stated that the distance which beaver will go from water to obtain food and raw material for huts and dams depends on presence or absence of predators. When these are absent, distances could be 140 m and over. When they are present beavers will not go more than 25 m from water. This author considered muskrat as an amphibious rodent which lives all the time in water. Biomass harvesting can produce negative effects on these species if done in the land surrounding water bodies (table 32). Beaver should be more affected and habitat disruption would be of a short term since regeneration would then favour these herbivorous mammals. Removal of logging residues will probably intensify negative effects on these mammals since residues will not be available for food or raw material (dams and huts). Aquatic plants also represent an important part of their diet. Dryade (1980) indicated that intensive clearcutting can significantly increase water temperature, nutrients and consequently favour aquatic plants. Hypothetically, increases of food and raw material might turn out as being detrimental to forest managers since populations would increase greatly. Moore (1940) described damage to Douglas-Fir regeneration caused by beavers.

Forest biomass harvesting can also be detrimental to waterfowl of this life form. Effects will be more important if trees are logged right along river, stream or lake banks. These species (mallard, wood duck, pintail,...) will be more affected than beavers and muskrat since they usually nest in upland habitat. Removal of residues and unmerchantable trees or shrubs will reduce hiding cover essential for protection while nesting. A major impact is predicted if harvesting is done within this period.

Logging systems which require two or three operations would only increase the negative effects. However such effects are of a short term. Schultz (1973) stated that aquatic habitats of waterfowl will be unaffected by upland logging.

It could be predicted that some species classified under this life form and inhabiting natural openings (American Woodcock, common snipe,...) will be favoured by logging activities. Other species

Table 32. Interactions between forest biomass extraction and selected wildlife species of life forms 3.1 to 3.5: Description of potential effects and mitigative measures

Life form and species	Activity	Direct effects	Indirect effects	Mitigative measures
3.1 Beaver, Muskrat	- Clearcutting	- Increase of water temperature, nutrients and increase of immersed and emerged aquatic plants	- Increase of food, population and consequently damage to new crop	- Favor trapping in areas of high beaver density
	- Residue removal	- Loss of food and raw material for dams and huts	- Short-term reduction of population	- Keep a green belt intact around lakes and along rivers and streams
Waterfowl	- Residue removal	- Loss of hiding cover for nesting	- Reduction of population	- Keep a green belt intact around lakes, and along rivers and streams
	- Season of operation	- Nest desertion if logging occurs while nesting	- Reduction of population	- Limit logging activities in areas of high potential when nidification occurs
Trumpeter Swan, Piping plover	-	- Habitat destruction	- Reduction of population	- Identify areas used by these species and restrict access when nidification occurs
3.2 Snake		- Reduction of preys (small mammals) and hiding cover for protection	- Reduction of population	- Census of species inhabiting managed areas - Leave uncut buffer strips, widths varying with species involved. Special protection of downed logs
Whooping Crane, White Pelican, Sandhill Crane, Double-crested Cormorant, Western Grebe, Common Loon	- Human presence - Harassment	- Raise of hunting pressure - Colony abandonment	- Reduction of population	- Protection of breeding ground and migration corridors
3.3 - 3.4 Wood duck, Goldeneyes, Bufflehead, Mergansers, Bald Eagle, Osprey...	- Clearcutting - Snag removal	- Loss of nesting sites	- Reduction of population	- Construction of artificial nests (wood boxes of different sizes) - Keep a green belt intact around lakes and along rivers and streams - Favor protection of snags and overmature trees
3.5 Reptiles and Amphibians	- Clearcutting	- Modification of water content of oxygen, temperature and turbidity	- Reduction of reproducing success	- Keep a green belt intact around lakes and along rivers and streams
	- Residue removal	- Reduction of prey and dens	- Reduction of population	
	- Harassment		- Reduction of population	

(mallard, wood duck,...) occasionnaly nest in trees (Harrison, 1975). These birds will react similarly to species of life form 3.3. Other species, Green-winged Teal, for instance, can sometimes nest 400 m or more from water (Harrison, 1975).

Piping Plover and Trumpeter Swan, both vulnerable species, are also part of this life form. As the former nests on gravel and sandy beaches and the latter prefers muskrat huts (Godfrey, 1967), the overall effects of intensive harvesting should be minimal. However, the loss of any of these control habitats within the range of these species would seriously reduce populations.

Species of life form 3.2 are semi-aquatic carnivorous animals which reproduce on the ground. Reproduction requirements would be affected by complete extraction of biomass. Most of these species are rare, threatened or endangered and as there is little information available, effects of intensive forest management can not be described. It however can be predicted that the overall effect of forest biomass harvesting would be negative as it contributes to reduce prey (small mammals) and hiding cover for protection. Snakes particularly use logs for protection (Melançon, 1961). Many turtles of this life form feed in water. The increase in temperature and sediment might favour amphibians and consequently turtles food. Finally these species are highly sensitive to human disturbance. The British Columbia Ministry of Environment (1980) identified the loss of habitat, the destruction of denning areas, and the tendancy of many people to kill reptiles on sight as being the major source of conflicts with these rare animals. Gilhen and Scott (1981) associated these factors to the high vulnerability of reptiles.

This life form also includes some endangered birds. The Whooping Crane, for instance, has long been classified as endangered. Canada supports the entire breeding population. Although the breeding ground is protected within the Wood Buffalo Park, Markham (1978) stated that the migrating corridor shall also be protected.

Archibald et al. (1976) indicated a potential threat posed by the hunting of Sandhill Crane along the Whooping Crane migration corridor. Increases in human presence associated with intensified forest management will increase hunting pressure and thus be detrimental. Also the Great Sandhill Crane, rare in Manitoba, could also react similarly (reduction of population). Markham (1978) stated that for White Pelican, habitat loss has been limited in the past, but now the major limiting factor appears to be human harassment and disturbance causing nesting colony abandonment either completely or on an annual basis. Any forest activity if done in the surroundings of colony mainly while it is in progress will directly affect White Pelican. However, the species has very specific nesting colony requirements (inaccessible untreed islands) the loss of habitat appears to be improbable.

The Double-crested Cormorant is also vulnerable to human disturbance which is the largest potential limiting factor (Gollop, COSEWIC, 1978). The Western Grebe and Common Loon both nest near water bodies. The biomass extraction will not create direct effects although human disturbance can also affect populations.

Recreational spcies of this life form will react similarly to human disturbance. Furthermore, Dryade (1980) stated that a decrease of fish population consequent to a drop of oxygen and a rise in turbidity might generally affect species of this life form. However, as discussed for life form 4, this impact could be counterbalanced by a shift in species composition (cold water fish replaced by warm water fish).

Species of life forms 3.3 and 3.4 will react similarly to intensified harvesting as they also use aquatic habitats in search for food (herbs, insects, fish,...). Nesting requirements are different (tree nesters). Clearcutting and snag removal will be detrimental. In fact, many authors observed a drop of woodpeckers population after clearcutting. These primary excavator will not find similar forest conditions (dead and dying trees) until many years after clearcutting. Complete forest biomass extraction will thus generate significative impacts on these life forms.

INTERACTIONS BETWEEN FOREST BIOMASS EXTRACTION ACTIVITIES AND AQUATIC LIFE FORMS (4.1 TO 4.3)

Fish are generally considered as a very important component of wildlife first because of their recreational and commercial values and second because they are highly sensitive to any modification of water quality (table 33).

Species of life form 4.1 inhabiting cold and running water (creek stream, small river) are the most sensitive to biomass extraction. Small watercourses quickly react to sunheating and are very active to erosion and turbidity. Most of the species comprised in this life form belong to the Salmonids family (Brook trout, Coho salmon, Rainbow trout, Cutthroat trout, Aurora trout,...).

As noted by Hall and Lantz (1969), clearcutting produces important modifications to dissolved oxygen and water temperature. Schultz (1973) stated that increased water temperature resulting from removal of tree cover is a potential treat to fish in streams. Also stream turbidity is critical during the egg and alevin stages in several fish species, and also inhibits the occupation of certain streams by adults of several species. Comparing density of fish to water temperature, Narver (1970) observed a significative reduction of population before (6 010 fish per hectare) and after (3 507 fish per hectare) clearcutting. In this peculiar case, water temperature has raised from 15,1°C to 21,1°C. Greene (1950) recording similar water temperature changes has noted fish migration. Brown and Krygier (1970) clearly demonstrated modification of water temperature following clearcut, patch cut and uncut control (figure 10).

As already described previously (5.2.2.2) sediments originating from erosion (roads) can cause serious problems to spawning grounds and general fish habitat. Sediments reduce the survival

Table 33. Interactions between forest biomass extraction and selected wildlife species of life forms 4.1 to 4.3: Description of potential effects and mitigative measures

Life form and species	Activity	Direct effects	Indirect effects	Mitigative measures
4.1 Arctic char, Brook trout, Coho salmon, etc...	- Clearcutting and logging operation (including extraction)	- Increase water yield and streamflow, the increase being proportionnal to the intensity of cut	- Temporarely modify sediment movement and might interact with fish habitat - Alter and even displace spawning grounds	- Cut-over area not exceeding 50% of the area of watershed - Keep intact buffer strips along stream and river banks - Avoid concentrating cutovers at same altitude and exposition within a watershed
		- Increase suspended sediments and turbidity	- Salmonids will suffer from gill damage - Modification of the feeding behaviour by a change in invertebrate composition and by a modification of their visual keenness	- Keep intact buffer strips along stream and river banks - Remove part of man-made residues
		- Modification of insulation increase water temperature	- The increased temperature is especially detrimental to cold water fishes	- Keep intact buffer strips along stream and river banks
		- Increase of B.O.D. and decrease of dissolved oxygen	- Detrimental to cold water fishes	- Keep intact buffer strips along stream and river banks
		- Increase of acidity	- Release toxic metals contained in sediments of streams	- Keep intact buffer strips along stream and river banks
	- Increased human presence	- Overfishing	- Reduction of sport fishes population	- Define harvest policy before logging operations start
4.2 Kokanee Chinook Salmon, lake trout, etc...	- Clearcutting and logging operation (including residues extraction)	- Increase of annual flowing - Alteration of water quality is predicted on a middle or long term basis	- Increase of turbidity and siltation, scouring bed... - Modification of fish composition in long term	- Keep intact buffer strip around waterbodies
	- Increased human presence	- Overfishing	- Reduction of sport fishes population	- Define harvest policy before logging operations start
4.3 Northern pike, Muskellunge, Smallmouth Bass	- Clearcutting and logging operation (including residues extraction)	- Increase water temperature, sediment and turbidity - Decrease of dissolved oxygen	- Warm water fishes will be favoured. This species can gradually replace coldwater species	
River redhorse, Channel catfish, White bass, Cultips minnow		- Increase of turbidity	- These species are sensitive to increased turbidity	- Keep intact buffer strips around waterbodies

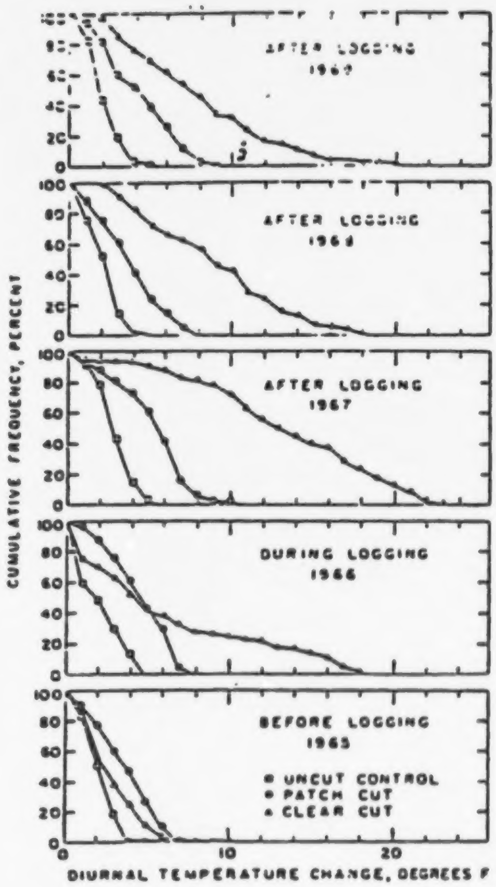


Figure 10. Cumulative frequency of diurnal temperature changes following clearcutting and patch cutting.

Source: Brown et Krygier (1970).

of eggs and alevins and decrease flow through the gravel, thereby limiting the supply of oxygen to the eggs. Dryade (1980) also stated that sediment reduces visual keenness of fish thus reducing predation capacity.

Calhoun and Sealy (1963) concluded that careless logging operations continue to damage priceless watersheds and to degrade important salmon and trout streams in California. Destructive practices include use of streambeds as roadways, operation of heavy equipment in streams, tractor logging on steep slopes and removal of streamside vegetation. Forest soils are eroded from the slopes and deposited in streams smothering eggs, fish and fish food. Organic logging debris may also pollute the stream.

Clearcutting also has an influence on the hydrology of watershed. Cutting generally results in increased water yield and streamflow, the increase being proportionnal to the intensity of cut. These changes in volume of water flowing in the streams could temporarily modify sediment movement and might interact with fish habitat. Some authors stated that forestry practices are compatible with increased water yield but not compatible with water quality (Goodell, 1971). There have been few comparative studies to determine the influence of specific cutting intensities on water quality (Bell, Beckett and Hubbard, 1974).

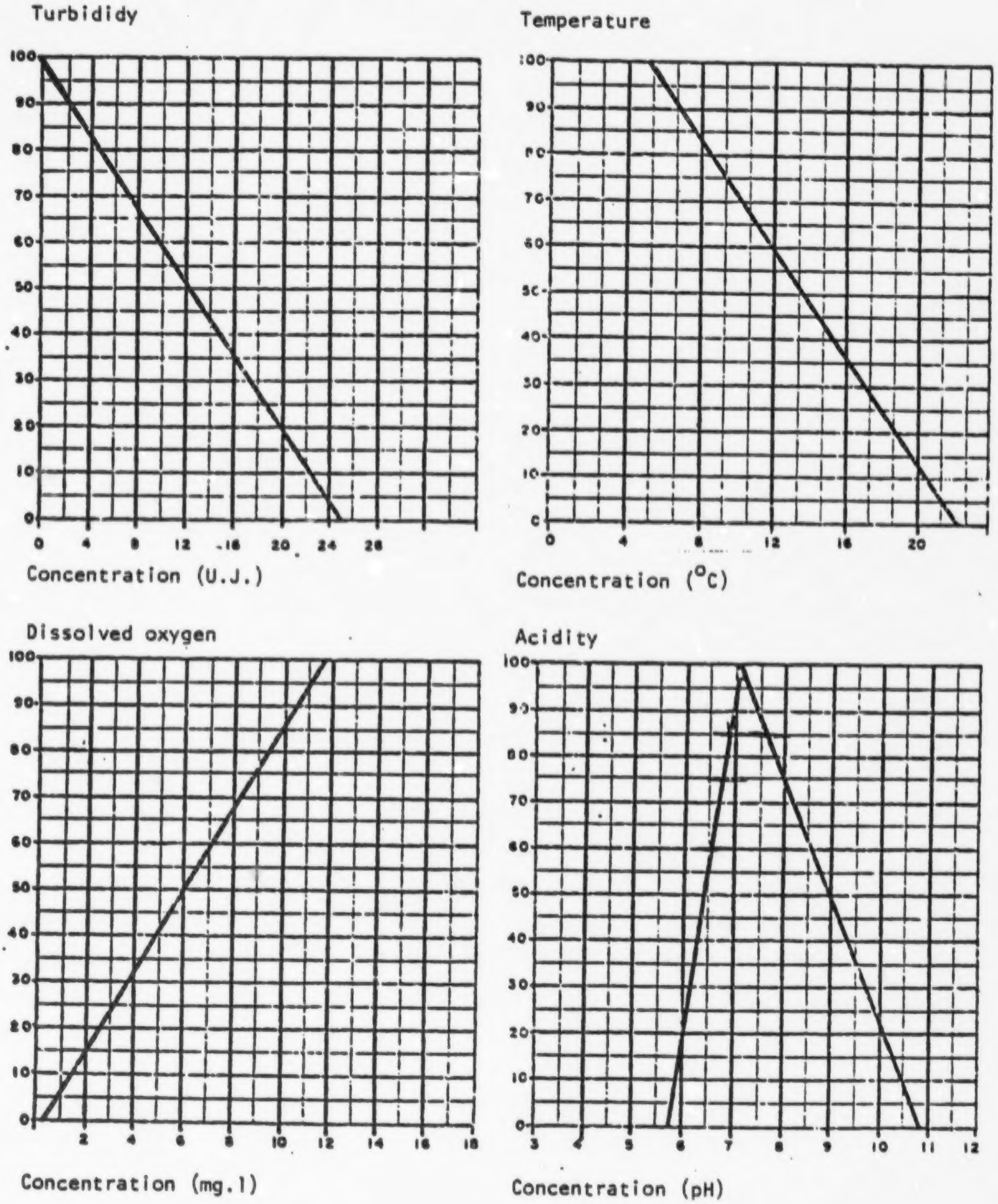
The Environmental Council of Alberta (1979) stated that after harvesting large clearcut blocks, the extra water produced may be valuable to some downstream users, but is likely to cause serious deterioration of the cold water fish habitat. The extra flow may channelize the stream, erode banks, and generally deteriorate the established pool and riffle pattern of the stream, but few hard data substantiate the magnitude of the problem. Poor timber harvesting and road building practices result in increased runoff, streambed scouring and excessive sedimentation, which kill fish eggs and even adult fish and destroy food supplies; water temperature increases, which may be either harmful or lethal to cold water fish populations; blockage of streams at crossing points, so that fish can no longer migrate to spawning or wintering areas; and erosion of stream banks, which removes important cover. Platts (1970) relating the effects of logging and road construction on the aquatic habitat stated that it will take the South Fork Salmon River watershed in west central Idaho an estimated 85 years to regain reasonable conditions but it could be brought back under a minimum rehabilitation program in a reasonable length of time for 5 500 000,00$.

Within the Complete Forest Concept, logging residues (branches, tops, stump, snag,...) can possibly icrease the overall effect on water quality. For instance, the lack of residual foliages and other debris to reduce surficial waterflowing and the decreasing of evapotranspiration are all facts that might increase negative effects (Dryade, 1980). It can be predicted that important water flowing increases might have repercussions on stream banks and stream beds and morpho-sedimentology. These modifications could alter and even displace spawning grounds.

Although main and hauling roads are the main agent of increased turbidity and that the road systems are not predicted to be different when complete harvesting of forest biomass, logging operations (including residues) will influence turbidity (Dryade, 1980). This increase of suspended sediments will generate similar effects than when building a road. Cold water fishes are generally intolerant to turbidity (figure 11). Salmonids, for instance, will suffer from gills damage (sealing), their feeding behaviour will be eventually modified by a change in invertebrates and prey composition and population and by a modification of their visual keenness. Furthermore, spawning and breeding areas might loose part of the carrying capacity.

As for turbidity, a complete forest biomass harvesting including shrub strata will modify insulation thus increasing water temperature (Dryade, 1980). The increased temperature is especially

Figure 11. Diagrams showing relationship between low tolerant aquatic organisms and physico-chemical parameters (temperature, turbidity, oxygen and acidity).



Source: Meunier et Guimond (1979).

detrimental to cold water fishes inhabiting small streams (figure 11).

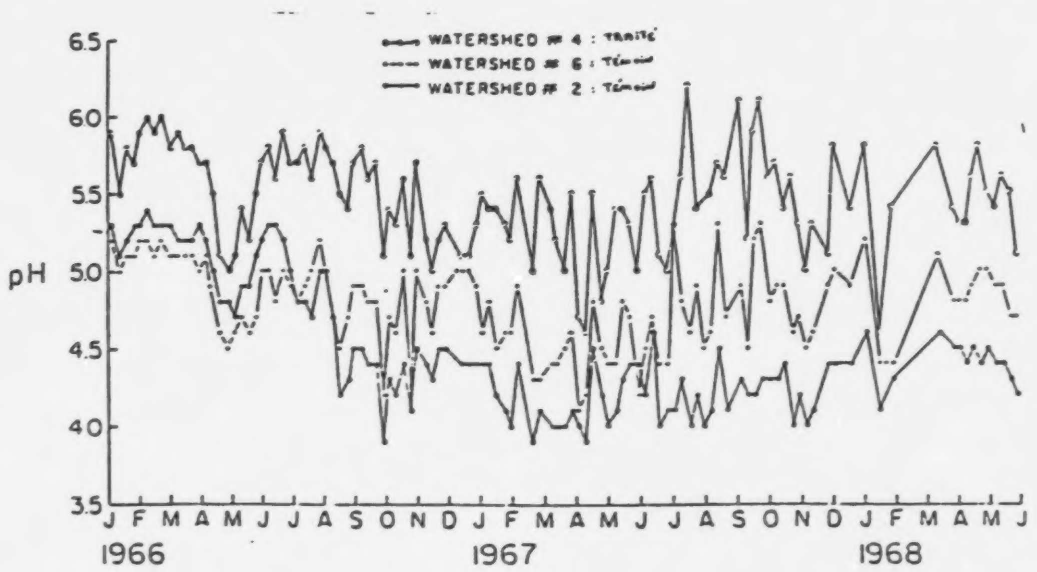
Conductivity or specific conductance is defined as a measure of the resistance of a solution to electrical flow. The resistance of the water solution to electrical current or electron flow is reduced with increasing content of ionized salts. The resistance is expressed in µmhos/cm (Wetzel, 1975). The level of conductance of dissolved solids generally reflects the level of mineral nutrients within a water body. These minerals are very important indicators of water productivity and are governed by contributions from the rock runoff of the drainage basin, atmospheric precipitations and the balance between evaporation and precipitation (Fournier, 1978). This parameter thus reflects the richness of water. This parameter, when related to temperature variations, modify the Biological Oxygen Demand (BOD) which reflects the overall bacterial activity. The Biological Oxygen Demand might be modified by complete harvesting of forest biomass (Dryade, 1980). Dissolved oxygen (mg/l) indicate how much air is present in water. Diminution of oxygen concentration generally result from two causes (Dryade, 1980);

- physical: increased water temperature
- biological: increased bacterial activity and consequently increase of the biological oxygen demand.

Acidity of waters is also an important parameter when evaluating the impact of forest harvesting on aquatic habitats (Dryade, 1980). Variations of bicarbonates, carbonates and hydroxides and the release of organic acids from forest litters are major causes of this evolution. Likens _et al._ (1970) have registered an increase of water acidity after forest clearing (figure 12) and ranging from a pH of 5,1 to 4,3.

According to those authors, the noted acidification comes from an increase of the nitrification process following cutting. Whereas

Figure 12. Variation of acidity of a cleared watershed, compared to 2 untouched watersheds.



Source: Likens et al. (1970).

in the undisturbed system, nitrogen is cycled conservatively between the living and decaying organic components, in deforested areas, nitrate produced by microbial nitrification from decaying organic matter, is rapidly flushed from the system in drainage waters.

Finally, the effects of rain on cutovers without residues can reduce the buffering capacity of the soil and increase acidity. Seepage lakes and lakes of igneous rock catchment areas are less well-buffered and more acidic than for calcareous hardwater lakes (Wetzel, 1975). The increase of acidity enhances other chemical transformations which release toxic metals such as aluminium, mercury and lead contained in sediments of streams, rivers and lakes.

As coldwater fishes are highly sensitive to these parameters, complete forest harvesting on large areas of a watershed will modify water quality (temperature, dissolved oxygen, acidity,...) and the morpho-sedimentology of streams (silting up spawning and breeding grounds).

Species of life form 4.2 possess similar requirements than life form 4.1. They have been classified under separate life forms mainly because of the size of water bodies involved. It is predicted that the effect of forestry activities on lakes and large rivers would be less significant than for small rivers and streams. The high water volume involved in lakes for instance, would require the cutting of large areas before modifying the overall temperature. It is generally accepted that cutting increases water flowing of a watershed mainly because it reduces water evaporation by trees and modifies distribution of precipitations. The increase of annual flowing in a drainage system leads to changes in water courses characteristics (erosion, water quality), mainly in spring (snow melting) and in summer and fall (season of most rains). The effects on fish could be similar than for smaller tributaries (increase of turbidity and siltation, scouring bed,...) (Anonyme, 1977).

Anderson and Trobitz (1949) observed that peak discharges and sediment deposition from watershed during a major flood were found to be quantitatively related to forest cover density and other watershed characteristics. Forest fire as a principal cause of cover differences had an important effect in increasing peak discharges and erosion during flood.

However, Aubertin and Patric (1970) stated that in an Appalachian watershed, during the first year after logging, clearcutting had no significant difference on water quality. Anonyme (1970) gave evidence from several studies on potential watershed damage, showing how logging practices increase sedimentation, raise stream temperatures, increase leaching of organic matter, and reduces the oxygen level of salmon spawning areas.

As these species reproduce and feed in lakes, large rivers, clearcutting could be detrimental. Lake trout for instance spawn on rocky or gravel bed of inland lakes, at a depth of 12 m or less, sometimes 1 m or less. Spawning in rivers has been rarely observed (Scott and Crossman, 1974).

Many species of this life form move from shallow waters to deep waters when water temperature is increasing. This is the case for Lake sturgeon. Other species (Coho salmon, Kokanee and Lake whitefish,...) must lie in deep waters when surface is heated because they cannot tolerate warmwater conditions.

Although the effect of forest biomass harvesting appears to be less detrimental on short term, modification of fish composition following alteration of water quality is predicted on a middle or long term basis. The modification will be more important if most of the watershed is cut. Wetzel (1975) described clearly the eutrophication process of a lake. He stated that the first apparent changes in the early stages of eutrophication is the enhancement of growth of fish. As eutrophication continues, however, with the accompanying progressive acceleration of decomposition and oxygen reduction in the tropholytic zone, stenothermal fish such as the trout and whitefishes are restricted to smaller and smaller volumes in the oxygenated area.

Eventually, these species are eliminated and replaced by warmwater tolerant fish species. Many of the changes associated with eutrophication (changing littoral zone, siltation,...) also affect the reproductive success of fish populations by reducing the survival of the young.

Warm water fishes of life form 4.3 are believed to tolerate more easily variations of their habitat specially increased water temperature and turbidity. Dryade (1980) stated that forestry practices related to biomass extraction do not intensify impact on warm water fishes. For instance, Pickerel are fairly tolerant of a wide range of physical and chemical conditions. Scott and Crossman (1973) reported optimal water temperature for Pickerel up to 25°C and further stated they can withstand temperatures as high as 32°C. Additionnal information on tolerance levels is exemplified by chain pickerel which withstands oxygen levels as low as 0,4 - 0,3 ppm., pH as low as 3,8 and temperature of 36,7°C (Carlander, 1969). Among the major factors limiting successfull natural reproduction are cold water temperatures (Oehmcke et al., 1958; Buss, 1960).

Other species of this life form could be affected by turbidity and by an increase of waterflow. Scott and Crossman (1974) stated that the River redhorse, the Channel catfish, the White bass, the Cutlips minnow are sensitive to increased turbidity.

It is predicted that warm water fishes will be favoured by forest biomass harvesting and can gradually replace coldwater species.

5.2.3.3- Mitigative measures and general recommendations for studies to fill information gaps

Mitigative measures applied to extraction practices are derived and adapted from conventionnal forest management. For instance, green belts preservation systematically recommended when logging will also be applied when harvesting biomass on a large scale. Other measures will be more specific as to protect rare or endangered species. These measures are however restricted to data available in literature and are divided in three major groups depending on terrestrial, terrestrial - aquatic and aquatic life forms.

MITIGATIVE MEASURES RELATED TO TERRESTRIAL LIFE FORMS (1.1 TO 2.8)

The important loss of food and shelter for mammals and the destruction of nesting sites for upland birds and reptiles inhabiting mature forest stands (life form 1.1 to 1.8) could not be totally alleviated by specific measures. Reduction of the size of clearcuts appears to reduce detrimental impacts for woodland caribou (table 30). Freddy (1974) recommended selective and small patch logging as alternative to extensive clearcutting. In high capability areas for caribou, Freddy (1974), in the low elevation Southern Selkirk and Purcell Mountains of British Columbia also recommends to:

- maintain a mature (130 years and older) forest canopy to assure availability of understory plants used as forage by caribou from October into February; to intercept snow thereby reducing the depth of snow on understory vegetation and to also provide arboreal lichens as the animal becomes increasingly dependant on lichens for food as snow pack depths increases.
- to utilize wide stream and/or lake buffer strips (greater than 100 m) to incorporate mature timber stands located in adjacent areas. These buffer strips would not necessarily

need to be on both sides of a stream or lake depending on topography.

In higher elevation, habitat is usually along streams and in headwater basins and provide arboreal lichens used for forage by caribou from March into May. In these areas, logging is stringently restricted and sometimes not recommended. Small patches (8 to 25 ha) could be harvested if areas are not suitable for caribou from the stand point of topography, timber type, and lichen availability. If portions of clearcuts are narrow in width (60 to 100 m), it will probably not be a barrier to caribou movement. In high elevation habitats, larger buffer strips should be maintained (200 to 300 m) to serve as a movement corridor for use by all ungulates between headwater basin and low elevation habitat areas. If contraints of windthrow, regeneration and economic cost can be overcome, cutting (group selection or partial) may be feasible over larger areas. Research is needed to insure that such cutting methods would not be detrimental to caribou from the stand point of arboreal lichen production and availability.

In Alberta, Schultz (1973) stated that the shyness and vulnerability to hunting of woodland caribou would add to the desirability of retaining areas from development or hunting activity.

Removal of tops and branches from treated stands might also be detrimental to caribou on short term basis. Although no author discussed the problem, it could be predicted that harvesting first the commercial stands (summer or fall), then residues (next growing season) could supply temporary forage for caribou. However, a large accumulation of residues could impede game movement in cutovers.

Removal of snags and old trees from large areas may contribute to disappearance of foci of lichen. Ahti (1962) suggested that preservation of old lichen-bearing snags in spruce-subalpine fir forests may serve as foci of lichen dispersal and so benefit woodland caribou in the Cariboo Mountains of Central British Columbia. As lichen spores are carried by winds over great distances, more studies should be undertaken to assess lichen dispersion from known foci to second-growth stands.

Studies conducted at Lakehead University by Dr. Harold Cumming in the past few years have pointed out that woodland caribou usually go to islands to give birth to their fawns. Use of certain lakes with many islands is quite predictable. Cumming has advised that logging not take place on such islands and that road access to the lakes should not be allowed. This is to reduce disturbance due to boating and fishing (Telfer, pers. comm.).

Removal of snags and fallen logs appears to be detrimental to small mammals (voles, squirrels, mice, chipmunks,...) and consequently to predators (lynx, fisher,...). In the absence of information on minimal amount of logs necessary to ensure viable populations of small mammals, it can be recommended that not fallen tree-trunks or other residues be removed from treated stands. Logs lying on the ground before cutting should be left if partly rotten as living organisms are already inhabiting such woody material. Thomas (1979) stated that when logs are lacking, some windrows, slash piles and root wads should be kept to simulate log habitats. As some small mammals represent a potential threat to future crops, studies should be undertaken to establish the exact amount of residues that should be left to satisfy both predators and forest managers.

Reservation of climax forest for food and shelter, buffer strips to assure migration, small patch logging and leaving part of the snags, logs and other residues could only be beneficial to other species of the life forms under consideration in this section (grouse, voles, grizzly bears, marten, owls, boa, squirrels,...). However, as these concepts are not yet documented in Canada, studies should be undertaken to assess these habitat - wildlife relationships and to sensitize forest managers to the importance of mature forests, to the detrimental effects of large clearcutting and the use of forest residues by wildlife.

These measures would also be beneficial to rare and endangered species. Analysis of these measures should be preceeded by basic studies to establish exact location of population, habitat requirements, limiting factors,...). For instance, Nero (1979) stated that more work should be done wherever Great Gray Owls occur to determine the status of local populations, numbers, movements, fluctuations,... Research is needed to determine whether these birds breed in Québec, where birds have been observed in summer, but where there is still no nesting evidence. Installations of man-made nests have been demonstrated successfully due to the fact that a lack of nests in some areas may be a limiting factor. Evaluation of preferred habitats across the range would be useful in order to establish the effect of forestry practices, peat mining and other factors affecting boreal forests.

For Grizzly bear, critical habitat (salmon spawning rivers and other summer foraging habitats, migration routes and denning sites) has to be identified and mapped so that possible impacts of human activities can be evaluated and precautions taken to minimize conflicts. Already information have been gathered and analysed in National Parks and along the proposed pipeline route in the Mackenzie Valley and Delta. In the United States grizzlies are classified as a threatened species and critical habitat is being defined and mapped with the aid of satellite imagery (Varney, Craigher and Summer, 1976). Perhaps extensive mapping is worth considering in the Canadian context (Macey, 1978). The British Columbia ministry of Environment (1980) considered the basis of grizzly bear management to be preservation of undisturbed habitat, hence the need to identify and protect such habitat against complete alienation or destructive forms of land use. Furthermore, information on the population dynamics, reproductive biology and habitat requirements of the grizzly is required. More information on research needs can be obtained from the ministry of Environment of British Columbia.

To reduce negative effects on Newfoundland marten, research studies and habitats protection measures should be pursued: estimation of the present day population, re-establishment of viable marten populations in other suitable sections of the island should be continued, especially where timber harvest is likely to occur and where human access is limited. More studies of the breeding biology of the species in Newfoundland are also required (Skinner, 1979).

Grey fox and Fox squirrel are rather unknown species. Basic studies should be undertaken (population, distribution,...) to enable the evaluation of interactions.

Raptorial birds (Hawk Owl, Long-eared Owl, Boreal Owl, Red-shouldered Hawk) are also classified rare or endangered species. Mitigative measures include protection of both critical nesting areas and key prey species. Before application of these measures, information on numbers and distribution should be gathered. Transplant of birds may be attempted where a species is threatened or endangered. Public education programs should be enforced to stress the value and vulnerability of the birds. As many of these species use snags for nesting, protection of old trees within critical habitat should also be encouraged. Clearcutting in relatively small patches may be beneficial in opening-up closed stands often providing more grassy growth and hence more small mammals.

Reptiles of these life forms (Pacific Rubber Boa and Rocky Mountain Rubber Boa) are rather unknown species. As these species are of low priority by the Fish and Wildlife branch of British Columbia, no specific study would be recommended. Any research on these species should start with an evaluation of population and critical habitat in the south-eastern part of British Columbia.

Many authors have suggested mitigative measures for ungulates of life form 2.1 (moose, elk, deer) (table 30). It is generally accepted by authors that cutting small blocks is more favourable to ungulates than cutting large ones (Huse, 1965). In the boreal forests, clearcut areas of 1,3 km² might be tolerated by moose. In the proceeding of the Seventh workshop on moose (1981) it has been suggested that mixedwoods being not removed from cutovers in the boreal forest (Brassard et al., 1974). Larger clearcut areas are probably not heavily utilized until the new stand has grown sufficiently to provide shelter (15 years or more after logging) (Telfer, 1974). In sub-boreal forests of north-central British Columbia, wintering moose utilized partial cutovers more heavily than clearcuts (Eastman, 1974). This author interprets this preference as a positive response to the fine-grained mosaic of cover and food producing patches created by partial cutting. Hebert (1978) stated that cut block utilization by moose was comparatively uniform, with a relatively high level of activity recorded at 160 m. In Québec, Vallée (1978) suggested limitation of clearcut areas to a maximum of 100 ha. Protection of winter shelter for moose is more critical than providing food as depth of snow is the main limiting factor in eastern Canada and in the western mountains. To meliorate conditions for wildlife and other forest uses, the Alberta Provincial government proposed a 50% removal pattern ground rule for timber harvesting and a 2 to 3 m regeneration before removal of residual blocks. The maximum retention period of residual block is 20 years. Depending on management zones, reglementation of harvest layout are the following (Henderson, 1977):

- cut block width: 150 to 250 m
- cut block size: 25 to 80 ha

This ground rule has been criticized mainly because the leave blocks were harvested too soon after the first cut and because of no real benefit as cover to wildlife. Large ungulates need 4,5 to 6 m trees for cover (Env. Council of Alberta, 1979). The 3 m regeneration provides hiding cover (in patches) for ungulates and some thermal cover but no «umbrella» to catch snow. It is inadequate for wildlife in the light of existing data. The simplest way to ensure better cover is to require a wait of over 20 years before re-entry to remove residual 50% of mature timber where large mature stands are involved (Telfer, pers. comm.).

In Québec, ground rules for minimal moose habitat protection are as follow (Anonyme, 1977):

- maximal size of cutovers: 15 km²
- shape of cutover must be designed in such a manner that from any point, the distance between leave blocks (minimum 3 ha) and cutover must not exceed 600 m
- leave blocks in cutovers must cover at least between 4 and 8% of the total area treated depending on average snow depth of the climate region

Cutting small blocks is particularly favourable for deer (Lyon, 1966) as it increases forage production. In Québec, maximum size of cutover should not exceed 80 ha and cutovers should be isolated by mixed or coniferous strips (minimum 125 m) of at least 30 years of age (Anonyme, 1977).

As most of the recommendations are based on local observations of ungulate behavior and have not been subjected to experimental tests, monitoring of areas cut to the prescribed system to evaluate the validity of the literature recommendations should be undertaken.

Also, the effect of residues removal in critical habitat could be overcome by an analysis of the use of residues by ungulates in wintertime and suggesting to forest managers the appropriate level of top and branch disposal. A two-step harvesting could then be worthwhile where animals use intensively this supplementary food.

Recommendations for residues disposal should be done to increase or restrict ungulates accessibility to browses.

Management of winter range must be done with great precaution since the high home range fidelity of white-tailed deer imply the return to the same winter range (Dryade, 1981). As complete biomass harvesting will be important in the mixed and hardwood stands where populations of deer are high, the overall impact on deer will be important. Monitoring of populations on public and private lands should be undertaken to prevent dramatic loss of critical habitats. Specific winter range protection should then be undertaken.

In cutovers for conventional forest harvesting, escape cover is partially made up of unmerchantable trees and shrubs. As these would also be harvested in the complete forest system a decrease in ungulate utilization is predicted. In mixed and hardwood stands, leaving patches of trees and shrubs should be worthwhile to increase escape cover and to increase diversity in tree species and variation in height of trees and three clumps within the next rotation.

To mitigate the effect of harassment on use of cutblocks by moose, Tomm (1978) suggested reduction in cutblock width (120 to 160 m), increased priority on cover maintenance and a minimum of 100 m side buffers between blocks. He also suggested smaller cutblocks (less than 30 ha) in high harassment areas. Cutblock sizes for deer are recommended to be at least 16 ha with maximization of block perimeters. Maintenance of minimum 100 m buffers between blocks would improve range balance. He also stated that further research is required to 1) define harassment stimuli in terms relevant to animal perception, and 2) define animal responses to harassment sources.

Many more studies could be suggested for deers. The B.C. ministry of Environment (1980) stated that more intensive management will require more knowledge of the size, characteristics and distribution of winter ranges, the populations they support as well as the timing of deer movements. Also other components of deer habitat have not been studies to any great extent (spring range, fawning areas and migration corridors). Further research is required to gain knowledge of deer-predator relationships, and of the various factors limiting deer management.

As little studies have been undertaken on the effects of clearcutting on upland birds and as it is predicted that logging residues would be detrimental, research studies should be undertaken to assess impact and define mitigative measures. However, Diggle and Addison (1977) stated that measures proposed for deer and elk will in large parts suffice for grouse as well. Any research study for management of ungulates should comprise upland birds as well. Dryade (1980) stated that forest operations in fall or winter would be less prejudicial than in spring or summertime when nesting occurs. Special attention in studies should also be given to the use of residues by upland birds and to define minimum amount necessary to maintain or increase populations.

Impact of forest operations being difficult to assess for species of life form 2.2 (foxes, coyotes, weasels,...) mitigative measures are based on very limited data. Any cutting methods increasing prey (small mammals, ruffed grouse, hares, deers,...) will be beneficial to these species. However, as they are highly adaptable to human disturbance, no priority is given to them.

An increase of prey species will also be beneficial to Peregrine Falcon. However, disturbance and nesting site destruction should be carefully monitored. Martin (1978) stated that there is a need for strong legislation to protect individual Peregrine and their breeding habitat. Successfull reintroduction into southern Canada depends upon a high degree of protection. There should be population inventories in wilderness areas before development so conflict areas can be identified and solutions worked out. Also guidelines should be developped for the protection and management of the species in areas where development occurs.

The management consideration for Kirtland's Warbler should be increased in the coming years. As it inhabits young jack pine forests of south-central and southern Ontario, cutting mature forests should be done to regenerate suitable habitat in localities where nesting has occurred. However, before management can be practicable, more studies should be undertaken to understand the biology of the bird population in Canada (Chamberlain, 1978).

Species of life forms 2.3 and 2.4 affected by human disturbance associated with harvesting operations, buffer strips of varying width should be kept intact around critical habitat of species. However, as these habitats are not actually identified, development of new territories should be preceeded by population census and potentiel habitat identification. Guidelines should be prepared in order to reduce habitat destruction and general harassment on raptorial birds (eagles, falcons, hawks), mammals (marmot, bison) and reptiles (snakes, lizards, both vulnerable groups of species). Other species (chipmunks, voles, deer mouse, snowshoe hare and porcupine) could also be monitored to assess population fluctuation before and after clearcutting as they represent key prey for carnivorous species and potential pests for forest managers. Specific attention should be given to the importance of residues as hiding cover so predators will not deplete populations.

Effects of intensifed forest management on mammals of life form 2.6 (wolf, bear, cougar) are largely indirect and difficult to predict, specific measures to protect prey and ensure diversified habitats could only be beneficial. Guidelines to protect denning sites from disturbance could be prepared and applied when observed. As these animals are naturally rare within our forests and range over large areas, they should be protected from harassment, except when they present a danger to forest operators. With the increase of forest activities, specific surveys should be carried out to confirm the existence and distribution of the cougar in the Eastern Provinces and to gather information on its ecology for use in formulating a management plan that will ensure its survival (Van Zyll de Jong and Van Ingen, 1978).

MITIGATIVE MEASURES RELATED TO TERRESTRIAL - AQUATIC LIFE FORMS (3.1 TO 3.5)

Species of life forms 3.1 to 3.5 use terrestrial or aquatic habitats for reproduction and/or feeding. Protection of riparian zone is probably the most effective mitigative measure (table 32). In most provinces, ground rules to leave untouched green belts around lakes and along rivers and streams would permit to attenuate negative effects of logging on species of these life forms.

On -middle or long term basis, forest biomass harvesting could favor early successionnal stage tree species (aspen, birch...). In order to limit damage to regeneration, trapping could be favoured in areas where beavers are numerous.

Protection of green belts would also preserve nesting areas of most waterfowl species. Also, logging operations should be planned in order to limit human activities in the surroundings of these zones while reproduction occurs. It is recommended to harvest in the fall or winter.

Gollop (1978) recommended a careful management and protection of the breeding grounds and migration corridor of Whooping Crane. Markham (1978) suggested to designate nesting areas of Double-crested Cormorant as having protection status under provincial legislation. Regulations should prohibit habitat destruction and human disturbance. To prevent the latter, a no access half-mile limit around nesting colonies during the nesting season is recommended. Important foraging areas should be identified and protected from conflicting land use. Markham (1978) also recommended to apply similar rules to White Pelican.

To attenuate impacts on species of life form 3.3, it is essential to preserve or not remove part of the old, dying or dead trees (snags). Thomas (1979) stated that an alternative often suggested as a partial substitute for snags is to locate bird boxes throughout the forest. Nest boxes can be valuable for some species of secondary cavity nesters. In addition, reliance on bird boxes requires the placement of many types and sizes of nest boxes at various heights and densities. Boxes must be constructed, installed, cleaned and replaced periodically. Consequently, this substitute measure is very expensive.

Keeping intact a green belt around water bodies would at the same time favor the protection of existing snags essential for tree and cavity nesters. However, these birds are secondary cavity users, utilizing cavities dug by primary cavity excavator such as woodpeckers. To ensure the protection of these primary cavity excavators, Thomas (1979) recommended to consider snag requirements on a community by community basis: territorial requirements of each woodpecker species were determined from literature and the snag requirement for nesting of each pair (depending on the species).

Protection of green belts will also be favourable to amphibians and reptiles inhabiting riparian zones. They will find suitable shelter and food.

MITIGATIVE MEASURES RELATED TO AQUATIC LIFE FORMS (4.1 TO 4.3)

Mitigative measures to attenuate the effects of forest biomass extraction on species of these life forms must be elaborated in order to protect water quality of streams, rivers and lakes as well as riparian habitats (table 33). Coldwater fishes and especially salmonids are sensitive to temperature, oxygen and turbidity variations. Measures gathered in literature have been developped for conventionnal (without residues removal) harvesting.

In most provinces, it is usually recommended to keep a green belt or buffer strip intact along streams and riversides and around lakes. In Québec, the recommended ground rules (Anonyme, 1977) are:

- Around small lakes (8 km^2 or less), the width of buffer strip should be 60 m if no cutting is made within this zone. It should be wider (approximately 90 m) if part of the trees are removed. In all cases, volume extracted should be lower than 30% and must be done in order to avoid openings reducing windfall problems.
- Around larger lakes (8 km^2 or more), a similar green belt should be protected on at least 50% of lake perimeter. Location of these belts should be located on slopes 10% and over.
- Along smaller watercourses, a 30 m strip should be kept intact when width of stream range between 3 and 9 m. A 60 m strip should remain intact along wider courses and in both cases on both banks. Along narrower streams (3 m or less) shrub strata should not be disturbed.

In Alberta, Henderson (1977) recommended that in the secondary watercourses (small but permanent streams), no disturbance of any kind or removal of forest cover will be permitted within 30 m of the high water mark except where specifically approved in writing following inspection by a forest officer. In main watercourses (major streams and rivers), no disturbance of any kind, or removal of forest cover, will be permitted within 60 m of the high water mark except where specifically approved in writing following inspection by a forest officer. On lakes and waterbodies with little or no recreational, waterfowl and sportfishing potential, exceeding 14 ha in areas, there will be no timber removal or disturbance of any kind within 100 m of the high water mark. On lakes with recreational waterfowl and sports fishing potential, exceeding 4 ha in areas, there will be no timber removal or disturbance of any kind within 100 m of the high water mark except after inspection and approval by an officer of the department. If such removal is approved, no machinery is to operate within 20 m of the high water mark.

Furthermore, stream bed destruction, particularly evident during the spring run-off with more rapide melting in cut-over areas, could be reduced by stream side buffers and cut-over area not exceeding 50% of the area of watershed. Van Groenewaud (1977) stated that properly designed buffer strips can prevent or at least ameliorate the deleterious effects of logging:

- no slash will be deposited in the stream,
- streambank erosion is kept at a minimum,
- unnecessary traffic accross the stream is prevented,
- increased exposure to direct sunlight and its resulting heating of the water does not occur,
- the buffer strip acts as a filter against sediment entering the stream from up-slope logged over areas,
- the terrestrial food source for aquatic life is not disturbed.

The buffer strip acts as a filter and barrier against overland flows of sediment that originates on the clearcut. The width of the required buffer strip thus depends on the slope, the rate of the precipitation or melt, the type of vegetative cover and the structure and texture of the soil (Van Groenwaud, 1977). Trimble and Sartz (1957) suggested a basic strip of 65 m that increases 60 cm in width with every 1% increase in slope.

The buffer strip protects the stream from full direct sunlight. The research showed that as the width increased beyond 7,5 m, the percentage of sunlight reaching a stream slowly decreased from 12% to about 4%. A buffer strip over 15 m wide is thus sufficient to protect the stream water from reaching temperatures detrimental to aquatic life.

Another aspect that should be taken into consideration while harvesting is the stabilization of overall water yield of a watershed. Every author agrees that logging trees within a watershed increase annual run-off by reducing evapotranspiration and affect distribution of precipitations (Anonyme, 1977). In Québec, the acceptable run-off increase is based on the hypothesis that the annual run-off can increase by 15% without damaging watercourses. The overall increase can be controlled by limiting the proportion of clearcuts within the watershed. Logging intensity has been established along with rotation period (approximately 100 years), type of basins and the hydrographic regions. It is also recommended to avoid concentrating cutovers at same altitude and exposition. Distance between two cutovers should be at least 150 m. A period of at least 15 years after regeneration should be waited before logging the residual strip between cutovers. It is also recommended to avoid clearcuts of 20 ha and over.

Dryade (1980) stated that complete harvesting of forest biomass on large areas can affect natural regeneration if not prevented by a specific cutting method that will provide seed-trees or if not planted soon after logging. Every management tool that is used to favour natural regeneration should be checked within the Complete Forest Concept: rotation length, width of buffer strips between cutovers, size of cutovers, cutting method,...

Also, as it is generally admitted that complete forest biomass harvesting might modify water quality at a higher degree than conventionnal logging, it will be important to test the efficiency of buffer strips and adapt width to new forestry practices.

The Environmental Council of Alberta (1979) stated that comprehensive studies should be initiated to rate and map watershed basins for relative sensitivity to various practices and operations. On the basis of these evaluations, changes in the ground rules may be desirable to maintain the production of clear, clean water.

COPE (1966) stated that with good planning and a reasonable amount of care, forests can be logged with little damage to streams. Also well managed forests can provide better stream conditions for fish than natural unspoiled forests and increased water yield by the gradual removal of mature timber can be beneficial to fisheries, especially when low summer flows are increased.

5.2.4- Stand regeneration and silvicultural practices

5.2.4.1- Description of activities

Stand regeneration and silvicultural practices comprise all activities to ensure a suitable regeneration and treatments needed to protect and improve timber crops.

Stand regeneration consists in ensuring the establishment of valuable (timber, pulpwood) tree species. This objective can be achieved naturally or with the assistance of various cultural practices:

- Scarification

  Scarification is a commonly used method of site preparation giving variable results ranging from humus displacement to stump uprooting. Usual objectives are:

  - helping the establishment of a natural regeneration;
  - preparing the soil to receive young plants (bare root or container stock);
  - preparing the soil for artificial seeding (aerial or terrestrial).

  On well drained, non organic soil (pine sites), scarification is often delayed over summer to permit slash to become brittle. D6, D7 or equivalent tractors, usually equiped with toothed or V-shaped blades of various designs, traverse the area along contours. The addition of heavy drags, constructed from old tractor rails, anchor chain, or fluked drums in tandem, has been an effective supplement to blading.

  On clayey or silty soils which have heavy accumulations of undecomposed litter, scarifiers suitable for well-drained soils do not expose enough mineral soils. Deep blading has been developped for these conditions. A developped blade is fitted with three spaced ploughs capable of creating three furrows approximately 30 cm deep during each pass. These blades are also used for drainage purposes (Schultz, 1973).

In Ontario, it is estimated that 20% of stands annually cut would require specific regeneration measures and 60% of these cutovers would require specific site preparation. In 1973, areas covered for scarification was foreseen to be 71 200 ha (Vézina, 1972).

In British Columbia, a total of 48 197 ha were treated in 1978, with one of the 13 different site preparation methods of which 17 109 ha were treated by mechanical methods. While this record is impressive, the production is still below the elementary goal. The amount requiring treatment could reach 120 000 ha per year (B.C. min. of Forests, 1980). Other methods could be applied to prepare the soil to receive seedlings. Chemical control of competitive vegetation and land drainage to improve soil productivity are possible methods. These techniques will be discussed in the Short-Rotation-Intensive-Culture Concept.

- Controlled burning

Slash burning is mainly used to reduce the competition of tops, branches, residues and competitive vegetation. In our general model, such residues are to be removed. Another objective of this site preparation method is to reduce the thickness of the humus layer to permit artificial or natural seedlings to be effective (Vézina, 1972). It is also used for reduction of fire hazard on slope too steep for scarification (perhaps a 30% slope) (Schultz, 1973). In the Sayward forest on Vancouver Island, where slash burning has followed logging, the loss of the soil organic layer has resulted in a substantial lowering of site productivity (Diggle and Addison, 1977). In our concept, this method will only be used on restricted areas where sivilculturally prescribed.

- Natural regeneration

Natural regeneration of forests depends on the remarkable capacity of plant communities to maintain themselves by natural seedling. In most cases nature permits the establishment of new forests, but not always composed of valuable commercial species. The challenge for foresters is to restock stands with valuable species. Unaided natural restocking following clear-cutting is the most common regenerating method used in Canada. Natural regeneration creates a high variability of vegetative conditions (hardwood, softwood, shrubs, grass,...). Conditions of satisfactory restocked stands is clearly expressed by the Alberta Forest Service. Each cutover must be examined before the seventh year following cutting. By a stocked-quadrat survey using milacre plots, 40% of milacres must contain an established seedling tree. Three quarters or more of the established seedlings must be spruce, pine or douglas fir, and the other one quarter or less must be balsam fir, birch or poplar seedling trees. Where a licensee has failed to reforest any area, he is obliged to reforest to the required standard by the end of the tenth year.

Natural regeneration is the cheapest way to restock a stand. It is usually done through cutting methods (Vézina, 1972):

- clearcut: cutting all trees of a stand in one operation; seeds to restock stand come from adjacent trees or from branches and tops lying on the ground.
- seed-tree cutting: clearcut in which isolated trees or groups of trees are left standing to ensure regeneration.
- shelterwood cutting: clearcut of a stand in successive short steps in order to promote the establishment of an even-aged regeneration under the canopy of residual trees.
- selection cutting (single-tree, strip or group): cutting of mature trees (isolated or small groups) only. Mostly applied in uneven-aged stands.

- Planting

  When natural regeneration fails to properly restock an area, it must be reforestated by planting or seeding. The past negative results with seeding have led to considerable reliance on planting (Shultz, 1973). These sites are usually scarified before planting in order to eliminate competitive vegetation giving a better chance for surviving. Species favoured in planting are mainly softwood (indigenous or exotic). Planting stock is chosen according to soil characteristics of the site. For instance, pines are preferred on dry sandy soils and spruce on well to imperfectly drained soils. Planting density averages 1 200 trees per hectare (1 tree every 2 to 3 m). Planting is done mechanically on level ground while hand planting gives better results on sloping grounds. In all provinces, millions of trees are produced annually to fulfill planting needs. Planting efforts should increase in the coming decades in order to maintain future timber supplies.

- Brush and weed control

  Newly regenerated areas have to be carefully monitored. In fertile, low-lying areas, the desirable species cannot usually compete with dense herb and shrub vegetation. This vegetation must be cut down, or treated with herbicides to prevent suppression of the coniferous trees. Once established, the trees will begin to outgrow the brush (Young, 1978).

- Pre-commercial and commercial thinnings

  When a naturally regenerated or planted stand reaches 10 to 15 years old, trees begin to compete with each other for the available sunlight, nutrients and water. The inferior trees are then cut down, releasing the remaining trees to continue growing at their optimum rate. Some stands might contain as few as 500 trees per hectare; others will have more depending on species involved. Unmanaged stands under 30 years of age can also benefit from spacing. Usually these stands are overstocked, their growth rate severely retarded, and many trees are too small for commercial use. A major waste thinning operation must then be carried out so the remaining trees can get full access to sunlight, nutrients and water. They will then grow vigorously and reach maturity sooner (Young, 1978).

Commercial thinning is applied to older second-growth stands where overcrowding is suppressing individual tree growth. Trees which otherwise would die are harvested and utilized economically, increasing the site's overall productivity (Young, 1978).

- Fertilization

Much of the forest land is deficient in nitrogen. Experiments have shown that an application of a nitrogen-based fertilizer, in conjunction with spacing or thinning can be very effective in stimulating tree growth in certain forest sites application (Young, 1978). An application of 84 to 112 kilogram per hectare of nitrogen (urea pellets) may be sufficient to stimulate rapid crown development for 3 or 4 years thereby permitting much greater and more rapid response to increase in growing space from thinning. However, because of the high cost of urea and the relatively short-term growth response, research is conducted to use nitrogen-fixing plants, such as legumes and shrub alders under forest stands.

- Improvement cutting

Many second-growth stands, for instance, in the Great-Lakes - St. Lawrence and Acadian forest regions, are of low quality and composed of species undesirable for actual market conditions. Silvicultural treatments prescribed to improve these stands comprise the elimination of undesirable species and poorly shaped trees. In even-aged stands this operation is defined as a timber stand improvement whether in uneven-aged or two-story stands, this operation is defined as a release cutting or conversion cutting (Vêzina, 1972). The most critical situation would be when all trees composing the stands are of low quality and the area should then be clearcut and planted with valuable species. Significant volumes of forest biomass may be extracted from these treated stands.

5.2.4.2- Description of interactions

INTERACTIONS BETWEEN STAND REGENERATION TECHNIQUES AND SILVICULTURAL PRACTICES ON LIFE FORMS OF TERRESTRIAL HABITATS (1.1 TO 2.8)

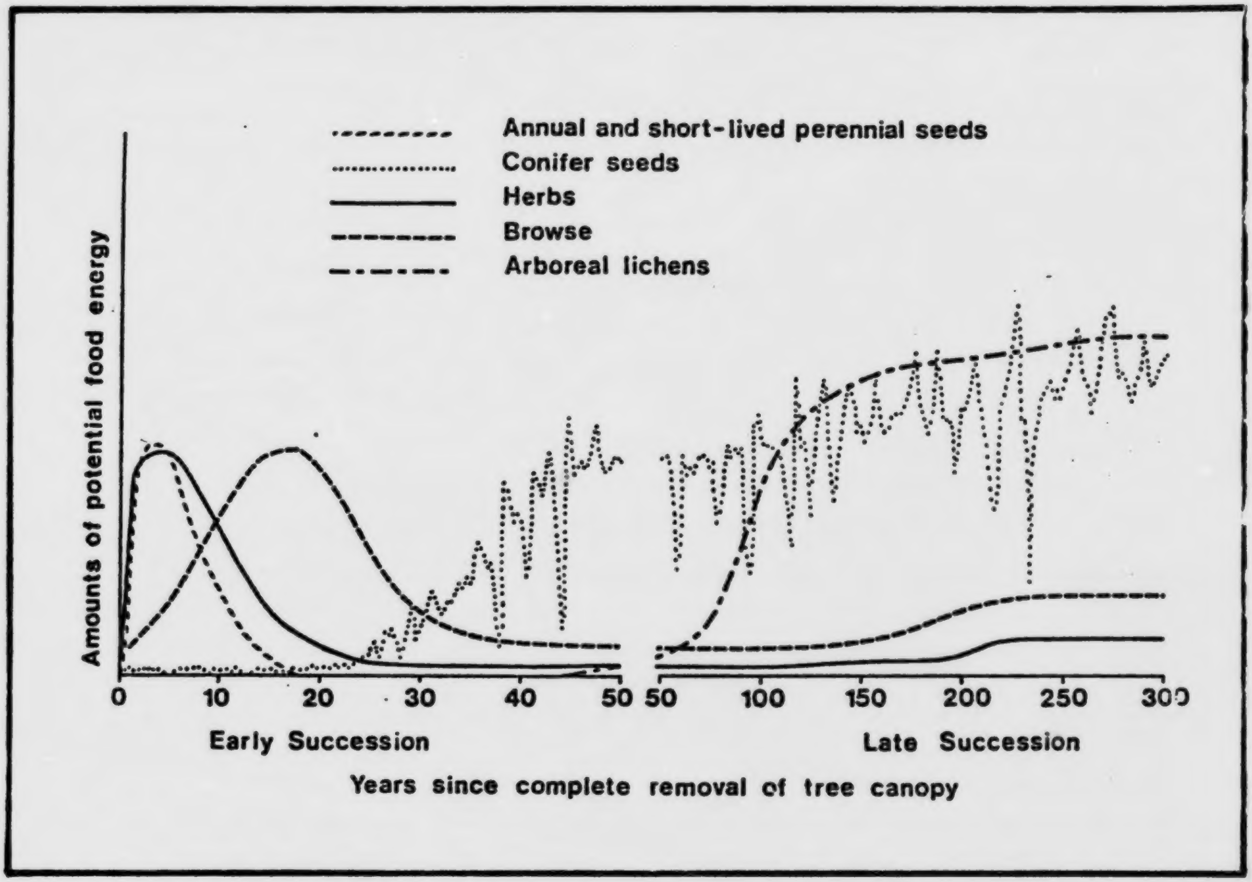
Life forms 1.1 to 1.8 (species related to mature forest stands)

As described in the previous section, species related to mature forest conditions are highly sensitive to clearcutting. Mitigative measures to reduce the effects were mainly to conserve intact different size of mature and immature stands within the area treated. But as time progresses, these forests will become overmature and, if uncut, will naturally die and be replaced by younger trees. It is thus important to assess the evolution of second-growth forest and to establish how long it will take before it is again suitable for these species. It is generally accepted that rotation of second-growth forests will be much shorter ranging approximately from 50 to 100 years. As arboreal lichen, for instance, are very slow growers and only present on old trees, woodland caribou might never again find suitable conditions (table 34). Seed eaters such as chipmunk, squirrel, are of low numbers in young forests until trees are producing cones. Snag and downed logs users (owls, boa,...) could also never find similar habitats. Figure 13 shows an idealized relationship between amounts of energy in different forms utilized by wildlife and time since removal of forest canopy (Bunnell and Eastman, 1976). Small mammals population could be lower in managed forests since logs are lacking to furnish shelter requirement. As voles and mice of these life forms are considered as potential pests, a decrease of population could only be beneficial to woodlands.

Table 34. Interactions between stand regeneration techniques and silvicultural practices and selected species of life forms 1.1 to 3.5

Life form and species	Activity	Direct effects	Indirect effects	Mitigative measures
1.1 to 1.8 Woodland caribou	- Reduction of rotation length	- Reduction of arboreal lichens for woodland caribou	- Reduction of population	- Extend rotation length enough to supply food (arboreal lichens) and shelter (snow-catch capability)
Fisher, lynx, boa	- Removal of residues from thinning and reduction of rotation length	- Reduction of downed logs as denning sites	- Reduction of population	- Leave part of the trees to reach downed logs conditions
Squirrel, marten, owls	- Reduction of rotation length	- Reduction of suitable nesting sites		- Leave part of the trees to reach overmature and snag conditions
Chipmunk, mouse	- Planting	- Damage to planted trees by girdling		- Rodenticide, control burning, removal of part of the downed logs
Yellow-bellied sapsucker	- Plantation and natural regeneration of yellow birch	- Damage to planted and natural trees		- Removal of snags in areas of high density of sapsuckers
2.1 to 2.8 Moose, deer, elk	- Planting	- Damage to planted trees by browsing limited to a 100 m strip around planted sites		- Increase the size of plantations; use physical barrier to impede game movement; alter palatability of planted trees, use alternative food
	- Thinning	- Shift to an earlier successionnal vegetation stage	- Improve wildlife forage for 30 to 40 years	- Reduce basal area enough to increase browse production (e.g. 17,2 m^2/ha)
	- Removal or residue (commercial thinning)	- Increase ungulates movement through treated stands		
	- Thinning	- Reduces escape cover	- Increase predation and hunting pressure	
Peregrine Falcon	- Human presence	- Abandonment of nests	- Reduction of population	- Any work undertaken from mid-February to the end of July should be avoided near nest sites
Kirtland's Warbler (South-central Ontario)	- Management of jack pine stands	- Reduction of habitat	- Reduction of population	- Respect of breeding requirement of the bird: dense clumps of trees interspersed with open grassy areas
Chipmunk, vole, cottontail	- Scarification - Planting	- Increase the horizontal and vertical diversity of wildlife resources; increase food availability	- Damage to planted trees by girdling	- Control of animal damage by trapping, poisoning, hunting,...
Vancouver Island marmot	- Reforestation or other silvicultural practices	- Disruption of behaviour - Reduction of habitat	- Reduction of population	- Monitoring of activities on Vancouver Island in accordance with the Fish and Wildlife Branch of British Columbia
Badger, Burrowing Owl	- Scarification	- Destruction of denning sites	- Reduction of population	
Deer mouse, Snow-shoe hare	- Fertilization	- Increase tree attractiveness to browsers - Increase carrying capacity for herbivores	- Damage to fertilized trees	
Porcupine	- Thinning	- Damage to residual trees by porcupine feeding on bark		- Adapt thinning intensity to porcupine behaviour
3.1 to 3.5 Beaver	- Planting	- Damage to plantation by flooding		- In area of high beaver density, plant trees out of the potential flooding zones
Wood duck, Bufflehead	- Reduction of rotation length	- Reduction of suitable nesting sites for upland tree nesters	- Reduction of population	- Around waterbodies, leave a few trees to become snag
Reptiles and Amphibians	- Reduction of rotation length	- Reduction of suitable logs for hiding cover	- Reduction of population	- Removal of man-caused debris, leave intact debris existing before disturbance
Whooping Crane, White Pelican, Trumpeter Swan	- Human presence	- Disruption of breeding activity		- No activity within 1 km from breeding sites
	- Fertilisers	- Increase quantity of food available to herbivores and increase number of fish available to carnivores	- Increase population - Change in fish species composition	

Figure 13. Idealized relationship between amounts of energy in different forms utilized by wildlife and time since removal of the forest overstory.



Source: Bunnell and Eastman (1976).

Life forms 2.1 to 2.8 (species related to other terrestrial habitats)

Species of life form 2.1 are active herbivores of immature forests (deer, moose, elk, grouse,...). Silvicultural practices would affect these species in many ways. Assessment of natural regeneration following clearcuts has been analyzed mainly in relation to management of ungulates. These large animals generally forage in cutovers by the fourth year after clearcut, provided they have timber for concealment and would utilize the cutover for both forage and concealment by about the tenth year. Winter shelter requires much longer, say 20 - 30 years from the time of cutting (Schultz, 1975). It is generally accepted by authors that regeneration of cutovers is sufficient to meet food requirement of most ungulates. Winter severity being the major limiting factor for ungulates, the availability of thermal and hiding cover in the vicinity of adequate food is essential to development of populations. Of all ungulates, moose is the most adapted to snow conditions. However, utilization of clearcuts for food decreases with the increasing size of cutovers. Hamilton and Drysdale (1975) have demonstrated that the use of clearcuts for food is decreasing with distance and becomes worthless at mainly 100 m from forest edge. Similar results have been obtained by Hunt (1976).

The Complete Forest Concept might however change the composition of food available for ungulates. In fact, the removal of unmerchantable trees and shrubs might favor herbaceous strata and stimulate suckering of aspen or other parent trees of shrubs. The absence of slash could also increase movement of ungulates in search of food in cutovers. Comparative surveys should be undertaken to assess differences within the range of ungulates involved in this life form.

Game birds such as grouse, woodcock, snipe and others appeared capable of thriving on cutovers once these are past the initial unvegetated stage. Ideal habitat for grouse consists of a mosaic of different age classes of timber, with natural openings and restocking cutovers (Schultz, 1973).

Eddleman and McLean (1969) imply that scarification or mechanical site disturbance has generally unfavourable effects on the amount and species composition of herbage. Stelfox (1962) found that forage production in clearcuts in white spruce forests of western Alberta was depressed by scarification for up to five years after logging. However, exposure of mineral soil by scarification in unburned clearcuts also stimulates growth of important browse species for moose, such as willow and paper birch. Diggle and Addison (1977) stated that existing ground cover may be an important source of forage that should be preserved when harvesting mature stands. Selection of forest site preparation treatments should accomodate such forage production needs where ungulates request high level of management. Schultz (1975) considered scarification as a medium threat of short term in small and large mammals. Hunt and Phillips (1978) also noted a short-lived reduction of forage production after harvesting and scarification.

Planting young healthy trees in cutovers at optimum distance could favour browsing of ungulates and rodents. It could be predicted that some damage might occur in the perimeter of planted sites for the first years as ungulates do not circulate far from hiding cover. When trees grow higher (hiding cover) it is predicted that browsing will increase but as the branches would be out of reach, damages should be limited.

Thinnings reduce basal area and canopy cover of the overstory. Bunnell and Eastman (1976) viewed thinnings as a shift to an earlier successionnal stage and expected the understory vegetation to respond with increased biomass productivity and perhaps nutrient levels in some species. Experience in western white pines stands have demonstrated that judicious thinning can improve wildlife forage values for 30 to 40 years. Thus the period of high browse biomass after clearcutting could be extended from the normal 10 to 15 years post-logging, up to 40 to 50 years if thinning took place 20 to 25 years after logging (Hungerford, 1969). Telfer (1974) found that residual basal area had to be reduced to 17,2 m^2/ha before browse production was substantially increased.

Spacing and thinning operations could have a negative effect on ungulates by reducing access through the presence of slash. Salvage of debris for energy conversion in thinned stands could turn out beneficial to ungulates movement. Removal of residues, representing insignificant volumes from juvenile spacing, would not be undertaken. However, logging residues from commercially thinned stands would be undertaken. The absence of residues will contribute to increase access by ungulates and hunters. Beneficial effects could be counterbalanced where hunting pressure is high. In fact, the increased accessibility for ungulates will also serve hunter's access. However, Diggle and Addison (1977) stated that thinning to improve forage conditions might be undesirable for three reasons:

- the understory may be virtually absent so growth response will be extremely small during the period of maximum canopy opening;
- the shrub layer may be dominated by one species that will choke the site before additionnal species can colonize;
- the species that do grow may not be preferred forage.

Little information exists relating intensive forest management practices on species of life form 2.2. Red fox, coyote, least and long-tailed weasels are all carnivorous species that prey on other mammals and birds. Silvicultural practices which would increase prey population would be beneficial to these animals.

Species of life forms 2.3 and 2.4 inhabiting meadows and fields would only be affected if these habitats are planted. As many of these are potential pests damage to plantation is predicted.

However, the intensity of damage would likely be small or limited to a narrow strip of stand perimeter. More studies are necessary to assess interactions. Concerning rare or endangered species, effects of silvicultural practices should not disturb greatly. The habitat of Vancouver Island Marmot which occupies alpine and subalpine areas of the higher mountains on Vancouver Island where forest production would be limited. As the limited quantity of suitable habitat is the ultimate factor limiting the population size, any reforestation program should be carefully monitored in accordance with the Fish and Wildlife Branch of the province. As the management of wood Bison implied reintroduction on potential sites, it might interfere with intensive forest management. As wood Bison utilizes an early successionnal stage for feeding, any forest management program in potential reintroduction sites should leave some areas unforested adjacent to managed forests.

The impacts of mechanical site preparation before planting have not been well studied (Bunnell and Eastman, 1976). These authors consider scarification as altering and generally retarding the rates of succession and provision of food resources illustrated in figure 12. They believe that impact depends largely on the severity of the disturbance. Light to moderate disturbance is probably beneficial as it increases the horizontal and vertical diversity of wildlife resources, but severe disturbance and compaction reduces the amount and productivity of habitat. Burrowing mammals and birds (badger, burrowing owl) of these life forms are probably affected by any degree of scarification or mechanical site preparation.

Species of life forms 2.5 and 2.6 classified as potential pests might interfere with the Complete Forest Concept. Bear along with other animals increase rapidly after logging. However, as succession proceeds, food becomes scarce and tensions possibly due to shelter requirement are set up. In this case bears may attack young regeneration (Lauckhart, 1956). Reoccupation time seems loosely correlated with physical size of the occupying species.

Birds and small rodents (mice, shrews, hare) normally move in within a year, and are followed by smaller predators (weasel, marten, fisher, fox, coyote,...) (Schultz, 1975). However, as stated previously, severe animal damage is usually quite localized and only relatively small areas are damaged enough to be of obvious economic concern (Harestad, 1978).

Fertilized, young natural or planted trees seem to attract browsers. As few data are available on the effects of fertilizing on wildlife, it can be said that wildlife often feed on commercial tree species. Fertilizers which enhance tree growth (ideal from the forester manager's perspective) often stimulate browsing (encouraging from the wildlife manager's perspective but disquieting to the forester) (Bunnell and Eastman, 1976). Stimulation of tree growth by fertilizing can produce two effects: increasing carrying capacity of managed forest for herbivorous species and consequently carnivorous species and also increasing damages by wildlife species to fertilized trees.

Thinning softwood stands where porcupine are present could be detrimental to managed forests. It is predicted that remaining trees would be severely attacked (barked) when high populations occur. In Fundy National Park of New Brunswick, porcupine is considered as a major cause of damage. In the western extension of the Park, about one fifth of the stands visited showed evidence of damage and in about one half of these, 25% or more of the trees on the sample plots were damaged or killed. Porcupines feed on the bark, mostly of young or immature trees (both hardwood and softwood) and often kill the trees by girdling (Hirvonen and Madill, 1978). As few basic data are available on rare or endangered species of these life forms (eastern cougar, turtles and snakes) interactions cannot be predicted. Concerning bobcat, western mountain lion, wolf and ermine, interactions with the concept will be dependant upon preys reaction to intensive forest management: more available preys = more animals.

INTERACTIONS BETWEEN STAND REGENERATION TECHNIQUES AND SILVICULTURAL PRACTICES ON LIFE FORMS OF TERRESTRIAL - AQUATIC LIFE FORMS (3.1 TO 3.5)

Except for beavers and muskrat, species of life forms 3.1 to 3.5 are either birds or reptiles and amphibians. Problems created by beaver to natural regeneration or plantation are limited to flooded areas (table 34). As managed trees are mainly coniferous, little damage due to tree felling is predicted. However, ponds created by beaver dams can inundate forest to an extent depending on the topography. Muskrat are usually encountered in marshes, swamps, ponds, lakes, ditches, slow-moving streams and also live in close association with the beaver, benefitting from the heightened and stable water levels created in ponds (B.C. ministry of Environment, 1980). Unless land drainage becomes a common practice to improve forest yield, no specific interaction is predicted. Land drainage is one of the most important threat for animals of these life forms.

Birds of these life forms are either waterfowl or endangered species. Waterfowl require aquatic habitats and for species such as Bufflehead and Wood Duck upland trees for nesting. Tree-nesting birds of life form 3.3 nest in large cull or dead trees around water which are rarely found in managed forests.

Other threatened species such as the Whooping Crane, White Pelican, Trumpeter Swan that are highly sensitive to human disturbance will also be affected by any human intrusions at critical times of the year, including intrusions associated to silvicultural practices.

Use of fertilizers to improve yield of managed stands might be beneficial to species of these life forms. For instance, a greater amount of nutrients in the water might stimulate growth of aquatic plants which will improve quantity of food available to herbivores and also increase number of fish available to carnivores, especially in regions of poorer quality soils like the

Canadian Shield. Little data are available to assess interactions. However, too much fertilizer might eutrophy water bodies and lead to changes in fish species composition.

INTERACTIONS BETWEEN STAND REGENERATION TECHNIQUES AND SILVICULTURAL PRACTICES ON LIFE FORMS OF AQUATIC HABITATS (4.1 TO 4.3)

Interaction with Fishes of life forms 4.1 to 4.3 are poorly documented. It is stated (Schultz, 1973) that whereas roads and harvesting constitute threats to the environment which can be minimized, silvicultural treatments constitute benefits to the environment which can be maximized. Only failures of these treatments will threaten the environment seriously. Of all activities related to stand regeneration and silvicultural practices, scarification, weed control, fertilization and increased human presences are potential threats to fishes of these life forms.

Schultz (1973) evaluated scarification or prescribed burn as a major threat on surficial sensitive deposits and consequently a medium threat on rivers, streams and lakes. He also considered restocking trees (prompt) as potential benefits to aquatic habitats while non restocking trees or slow restocking can be detrimental to these habitats. Chemical applications can also represent medium or major threat.

Smith and Wass (1976) indicated that burning can increase the amount of disturbance between roads by two to four or more times. This, coupled with an initial reduction of residual vegetation cover to near zero, means increased erosion potential.

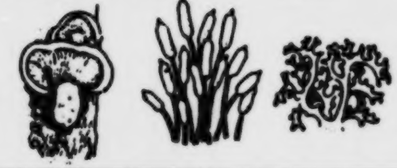
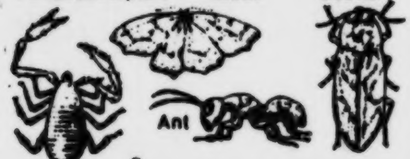
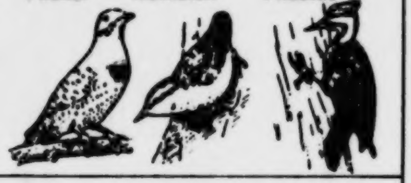
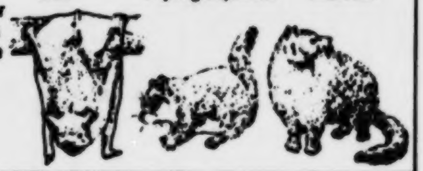
Moore (1974) in a study aiming to evaluate impacts of fertilization established that total amount of applied nitrogen entering streams draining treated areas are relatively small and should not have any measurable impact on eutrophication in downstreams impoundments.

5.2.4.3- Mitigative measures and general recommendations

Life forms 1.1 to 1.8 (species inhabiting mature stands)

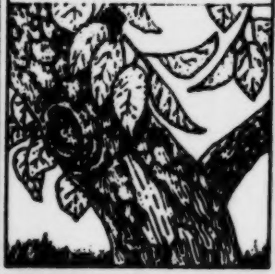
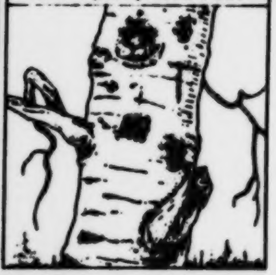
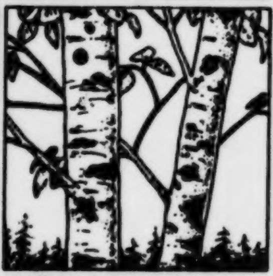
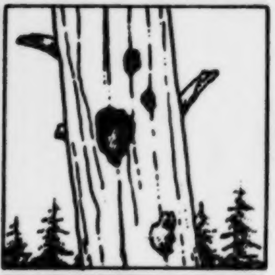
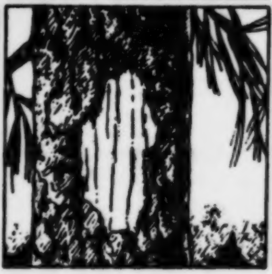
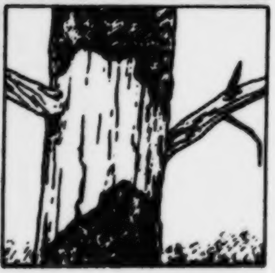
Shorter rotation being detrimental to species of mature forest stands, it is suggested in literature to reserved part of the managed forests to grow longer (e.g. 100 to 300 years in the mountains of British Columbia) (table 34). The Fish and Wildlife Branch of this province indicated that some stands should be retained long enough to develop a growth of arboreal lichen because of its value as caribou and winter deer food. However, much remains to be learned about the effects of second-growth management on arboreal lichen (Diggle and Addison, 1977). This recommendation could also be applied at different degrees for other species of these life forms. In any managed forest, part of the trees should be reserved to grow longer thus providing habitat for many wildlife species. Figures 14 and 15 show the importance of snags for wildlife. Snags provide a portion of the life support system for many species of plants, invertebrates, birds and mammals. They can be classified as either hard or soft. Hard snags are usually marketable but soft snags are usually without market value. Hard snags are essentially composed of sound wood, especially on the outside. Soft snags are in advanced stage of decay and deterioration. Table 35 presents a method of classifying snags (Thomas, 1979). There has been a recent surge of interest in retaining snags for wildlife habitat in managed forests. This interest has been brought about by the recognition that birds may play a significant role in regulation of insect populations. Many of the snag-dependant birds and mammals are insectivorous and represent a major portion of insectovirous forest fauna. Downed logs are also important as wildlife habitat. Figures 16 to 18 show a 5-class system of log decomposition. As there is little compiled information about the importance of snags and downed logs for wildlife within the canadian forest regions, it is recommended to enhance studies in order to gather basic data. These studies should be undertaken first within our major forest types (unmanaged and managed) to establish the quality and quantity of snags and logs and the actual use of these habitats by

Figure 14. Snags support many forms of life.

Form of life	Uses of snags	Examples
Fungi, mosses, and lichens	Decayed wood serves as a growth substrate.	Fungus Moss Lichen 
Invertebrates	Spaces under bark serve as cover and as places for feeding.	Pseudoscorpion Moth Beetle 
Birds	Cavities are used for nesting or roosting. Snags are used as perches and to support nests.	Flicker Nuthatch Pileated 
Mammals	Cavities serve as dens or as resting or escape cover. Areas under loose bark are used by bats for roosting.	Bat Flying squirrel Marten 

Source: Thomas (1979).

Figure 15. Most cavities occur in dead trees, but they may also be found in live or partly dead trees.

Type of cavity	Live trees	Dead or partly dead trees
Natural cavities		
Excavated cavities		
Spaces under bark		

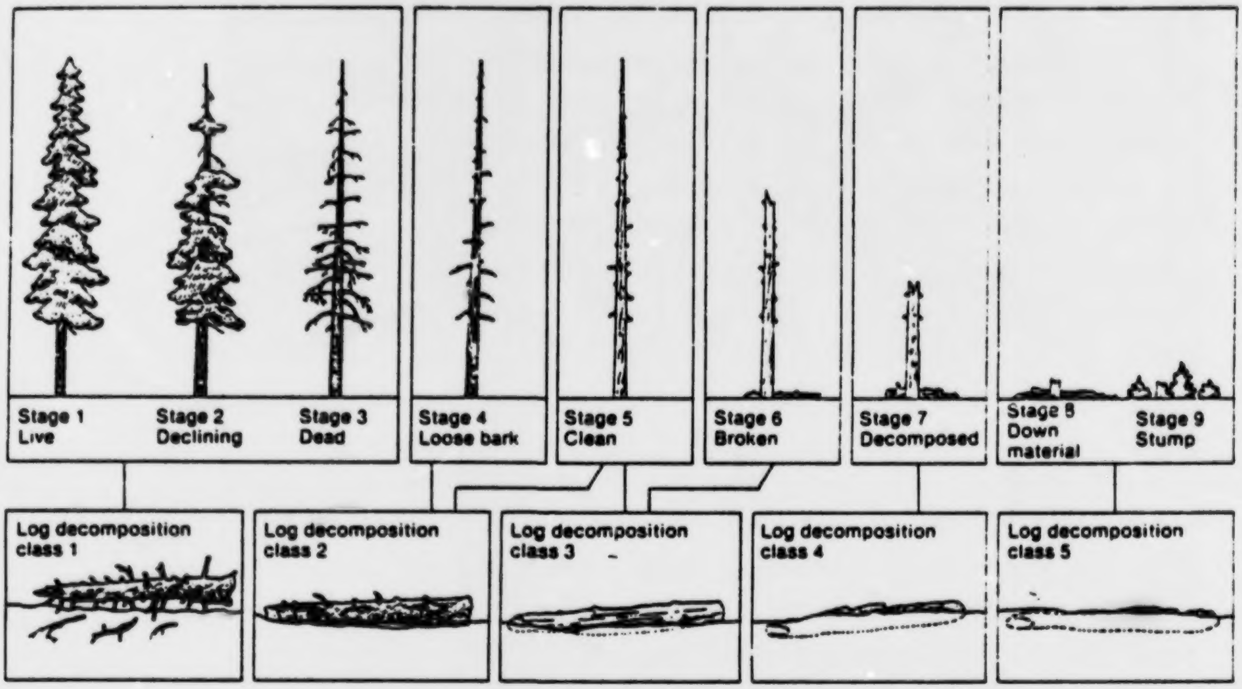

Stage 1
Live
Stage 2
Declining
Stage 3
Dead
Stage 4
Loose bark
Stage 5
Clean
Stage 6
Broken
Stage 7
Decomposed
Stage 8
Down
material
Stage 9
Stump
Log decomposition class 1
Log decomposition class 2
Log decomposition class 3
Log decomposition class 4
Log decomposition class 5

Figure 16. When they fall, trees and snags immediately enter one of the first four log decomposition classes.

Snag stage	Snag condition	Log class
1-3	Hard snag	1
4-5	Hard snag	2
5-6	Soft snag	3
7	Soft snag, 70% + soft sapwood	4

Log characteristics	Log decomposition class				
	1	2	3	4	5
Bark	intact	intact	trace	absent	absent
Twigs<3 cm (1.18 in)	present	absent	absent	absent	absent
Texture	intact	intact to partly soft	hard, large pieces	small, soft, blocky pieces	soft and powdery
Shape	round	round	round	round to oval	oval
Color of wood	original color	original color	original color to faded	light brown to faded brown or yellowish	faded to light yellow or gray
Portion of log on ground	log elevated on support points	log elevated on support points but sagging slightly	log is sagging near ground	all of log on ground	all of log on ground

Table 35. Snag conditions translated into log decomposition class (based upon work done on Douglas-fir).

Source: Thomas (1979).

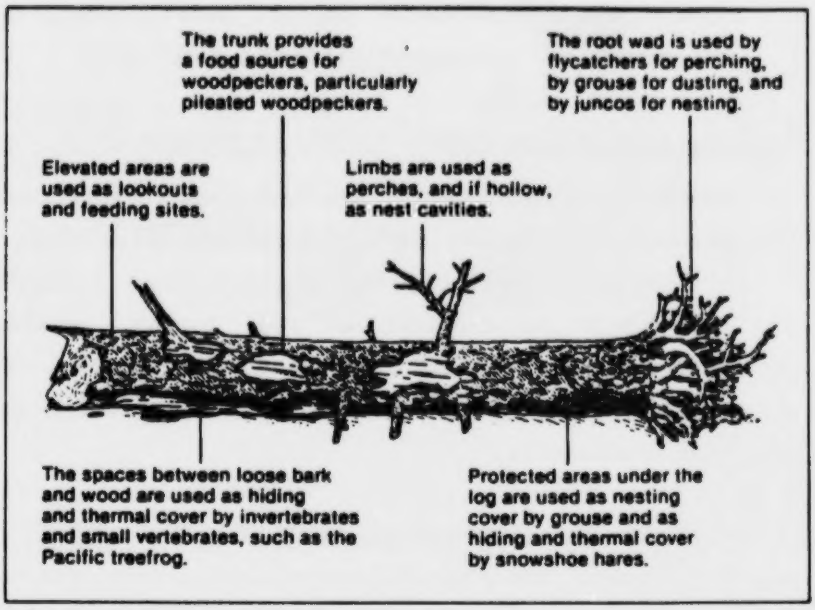

The trunk provides a food source for woodpeckers, particularly pileated woodpeckers.
The root wad is used by flycatchers for perching, by grouse for dusting, and by juncos for nesting.
Elevated areas are used as lookouts and feeding sites.
Limbs are used as perches, and if hollow, as nest cavities.
The spaces between loose bark and wood are used as hiding and thermal cover by invertebrates and small vertebrates, such as the Pacific treefrog.
Protected areas under the log are used as nesting cover by grouse and as hiding and thermal cover by snowshoe hares.

Figure 17. A class 2 log showing some of the structural features important to wildlife.

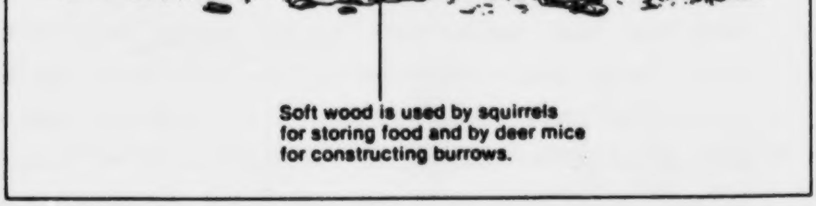

Elevated areas are much reduced but are still used as lookouts and feeding sites.
Low soft areas are used by grouse for dusting and by deer and elk for resting.
Soft wood is used by squirrels for storing food and by deer mice for constructing burrows.

Figure 18. A class 4 log showing advanced stage of decay and some of the structural features important to wildlife.

Source: Thomas (1979).

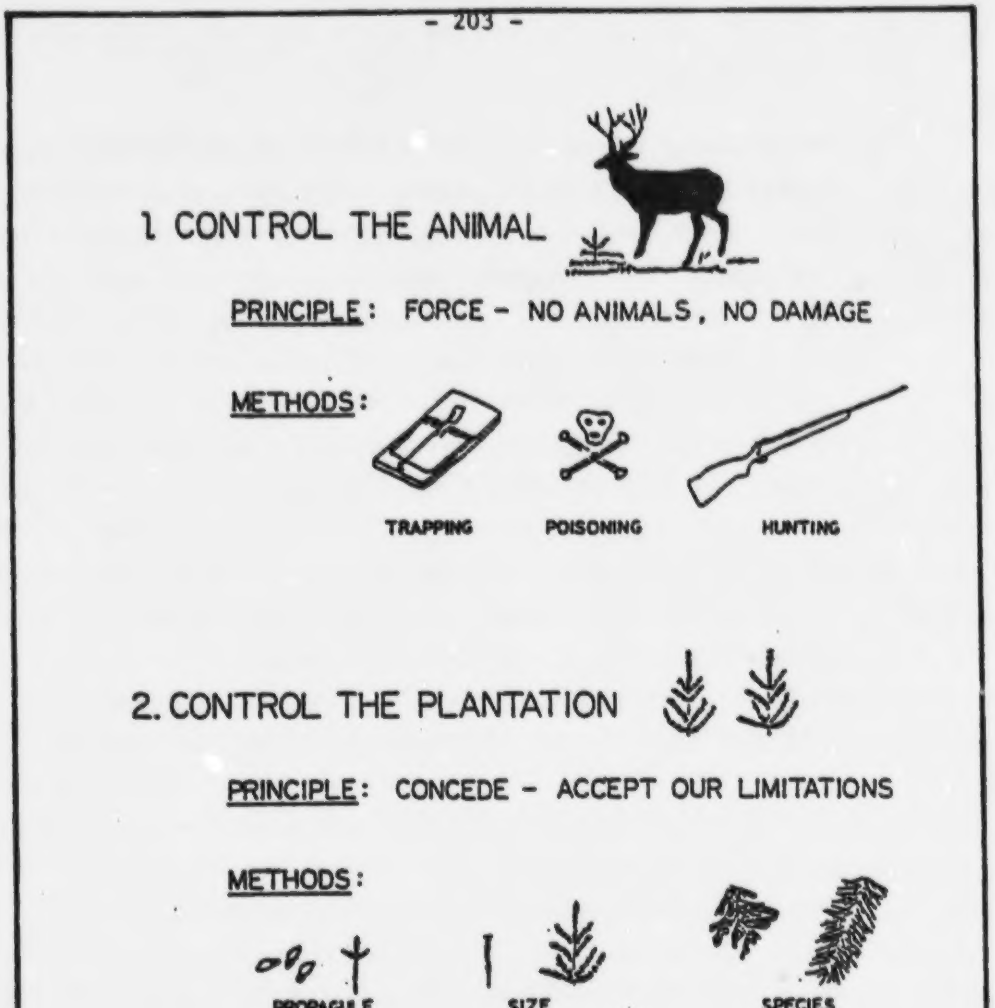
wildlife. This basic knowledge will help managers to prescribe silvicultural treatments taking under consideration maximum tree-growth and optimum wildlife habitat.

Life forms 2.1 to 2.8

Damage to planted trees by ungulates and rodents could be counterbalanced by different methods which are illustrated in figure 19. Most animal damage to plantation occurs as a result of feeding. This damage is manifest as seed losses, seedling mortality, suppression of seedling growth and understocking. Control measures have attempted to reduce animal damage through manipulation of three components:

- the animals (trapping, poisoning, hunting)
- control the plantation (propagule, size, species)
- interfere with feeding (alter palatability, physical barrier, alternative food)

Harestad (1978) stated that the most promising methods for the control of animal damage concern interference in the feeding process. This manipulation of habitat is designed to alter the abundance of alternative food. In some areas the preferred forage plants have been sprayed with defoliant in order to make the habitat less attractive to wildlife. In other areas, since herbs and shrubs are preferred over conifers, the plantations are seeded or planted with these species. This results in an abundance of preferred food items and shifts the browsing pressure from the conifers to the herbs and shrubs. The provision of alternative food has been successfull in protecting Douglas-fir seed from white-footed mouse predation. This protection can be achieved by sowing sunflower seeds and oats along with the conifer seed. The problem of animal damage in the management of plantations can be largely eliminated with the continued development of repellents and on increase understanding of habitat manipulation (Harestad, 1978).



1. CONTROL THE ANIMAL

PRINCIPLE: FORCE - NO ANIMALS, NO DAMAGE

METHODS:

TRAPPING
POISONING
HUNTING

2. CONTROL THE PLANTATION

PRINCIPLE: CONCEDE - ACCEPT OUR LIMITATIONS

METHODS:

PROPAGULE
SIZE
SPECIES

3. INTERFERE WITH FEEDING

PRINCIPLE: PERSUADE - EXPLOIT THEIR BEHAVIOUR

METHODS:

ALTER PALATABILITY
PHYSICAL BARRIER
ALTERNATIVE FOOD

Figure 19. Components and control of animal damage in forest plantations.

Requirements for moose, deer and elk must be examined in order to prescribe conditions of second-growth that will probably satisfy their needs (shelter, forage and escape cover). Experience and research permit the prescription of harvesting patterns in old-growth forest that will result in attaining high animal numbers, or in maintaining animals at prelogging numbers. No such experience exists in relation to second-growth stands. A habitat management program can be expected to at least double current numbers of animals (Diggle and Addison, 1977). Studies should be undertaken to help forest and wildlife managers to optimize second-growth forest management. For instance, complete harvesting of forest biomass can modify the following species composition that might favour or unfavour utilization by ungulates. Assessment of regeneration following complete harvesting of forest biomass should be made to establish if and how removing all trees and shrubs will affect species composition of the following stand. If so, use of the new stand by ungulates should be examined in areas of high animal densities and mitigative measures should be developped to favour preferred shrub species.

Other species considered rare or endangered could benefit from adapted silvicultural practices. Within the range of the Kirtland's Warbler, for intance, any practices that would involve jack pine stands should consider specific breeding requirement of the bird: dense clumps of trees interspersed with open grassy areas; pine must have living branches to the ground (Chamberlain, 1978). As Peregrine Falcon are protected from collecting or harassment under Game or Wildlife Acts in Canada, and are very sensitive to disturbance, any work undertaken from mid-February to the end of July should be avoided near nest sites (Martin, 1978).

As porcupine damage is common in Eastern Provinces and as no effective methods of controlling population has been successfull, it is recommended to enhance a study in order to develop and test measures to control populations.

Life forms 3.1 to 3.5

To prevent damage from beaver dams to planted trees, it is recommended to avoid planting within a potential flooding zone. This zone can be delineated according to topography, stream-side vegetation and watercourse characteristics. Another possible measure is to favour trapping within these zones.

Silvicultural practices in the surrounding of waterbodies should be done with precaution. In Québec, it is recommended to enlarge buffer strips if thinning or selection cutting are practised. This measure contributes to prevent windfall of residual trees (Anonyme, 1977). Also, to ensure suitable sites for upland tree nesters, management should provide for a few trees per hectare to attaining old age and become snags, otherwise, a specific requirement for these species would be lacking and population will drop.

Also, as all volume from thinned stands will be extracted, a lack of suitable logs for hiding cover of reptiles and amphibians could also result in a reduction of population. Thomas (1979) stated that in riparian habitats, man-caused debris should usually be removed, but the watercourse should not be overcleaned. Debris existing before disturbance by management activities might be left intact since it sometimes serves as a critical habitat component of reptiles and amphibians. On upland sites, management plans for residues should consider future availability of material to provide a continuing natural supply of debris. For instance, removal of all old trees near a stream would limit the supply of naturally-added tree limbs and trunks to the forest floor and streamedge in future decades.

5.3- The Short-Rotation-Intensive-Culture

5.3.1- Description of activities

The approach to define interactions of this concept with wildlife of concern will consider the development of a power generating plant, an ethanol or methanol mill all requiring large areas of land producing raw material at the proximity of the mill site, say a 40 to 50 km radius. The first step will be to locate the plan in an area where marginal farmlands are abundant and/or where large areas have been logged and suitable (productive land) for intensive culture. As these developments will cover extensive areas in southern parts of several provinces, promoters will have to prepare an impact study of the whole of each project to identify and assess impacts and define mitigative measures to attenuate negative effects. Alternative mill sites location within a given region must be comparatively analyzed to define the least detrimental site from environmental considerations. The following description of interactions is done to point out potential interactions of related activities on wildlife of concern.

According to the actual state-of-the-art of Short-Rotation Intensive Culture (SRIC) Concept, each of the management system described previously (3.2.2) (mini-rotation, midi-rotation and short-rotation) must go through a series of activities which comprises (Raitanen, 1980):

- Site preparation

  Objectives are to completely eradicate all competition from the site. This may be done mechanically, chemically, or through a combination. On old fields mechanical site preparation alone has not been effective. A combination chemical-mechanical procedure is most commonly used. Complete mechanical site preparation can be effective on a forest site immediately after clearcutting. However, planting must be done soon after.

Glyphosate (Round Up^{TM} by Monsanto) has been very successful on old fields when site preparation is accomplished by completely chemical means. When properly applied, (approximately 2 kg/ha), death of all target vegetation occurs within two weeks. There is no residue. After the application of glyphosate a pre-emergence chemical must be immediately applied to prevent re-invasion of the site. Table 36 summarizes main herbicides used for pre-emergence weed control.

- Weed control

Weed control may be mechanical or chemical. At high/intermediate tree densities, only chemical weed control is practicable. Herbicide residues are required to control plant competing with desirable species between harvests. It is not possible to enter a dense stand during a rotation to perform mechanical operation. Weed control is required until the planted trees have grown above the weeds (1 year for mini-rotation and 3 years with short rotation).

- Planting operation

Unrooted cuttings (25 cm x 20 mm) are the most common planting stock. Planting is completed during early spring when moisture levels are at or near field capacity. Midi-rotation and short-rotation stands are at densities acceptable for hand planting. Mechanization is essential in mini-rotations as densities are expected to reach 35 000 cuttings/ha.

- Harvesting

Biomass from energy plantations are harvested by whole-tree methods in the dormant condition. Through leaf-fall most nutrients will have been returned to the site. Midi and short rotations are harvested with feller-bunchers and chipped on site. The high density mini-rotation system must have specialized harvesting systems developped. A corn forage harvester has been used in 1 year old mini-rotations with some success.

Table 36. Preferred herbicides prescriptions by site (Rates in kg active per hectare) (for pre-emergence weed control in *Populus* x *euramericana* (Dode) Guinier)

Herbicide (common name)	Site: Loamy sand to sandy loam (imperfect drainage)	Site: Clay loam (imperfect drainage)
Amizine*(1) (Amitrole & Simazine)	1,7	4,8
Atrazine(2)	0,9	1,6
Diuron(3)	2,6	4,4
Metribuzin(4)	0,8	Not applied
Simazine(5)	3,1	3,8
Terbacil(6)	1,3	Not applied

Adapted from Raitanen, (1978, 1980) and Weed Science Society of America (1974).

(1) Amizine* : 3 - amino - s - triazole

(2) Atrazine : 2 - chloro - 4 - (ethylamino) - 6 - isopropylamino - s - triazine

(3) Diuron : 3 - (3, 4 - dichlorophenyl) - 1, 1 - dimethylurea

(4) Metribuzin : 4 - amino - 6 - tert - butyl - 3 - (methylthio) - as - triazine - 5 (4H) one

(5) Simazine : 2 - chloro - 4, 6 - bis (ethylamino) - s - triazine

(6) Terbacil : 3 - tert - butyl - 5 - chloro - 6 - methyluracil

Two year old mini-rotations would require larger and stronger equipment such as sugar-cane harvesters.

One harvested a coppice stand will develop at no additionnal cost from the existing root system. Coppicing will continue until the root system deteriorates.

- Drainage

Surface drainage is important in poplar plantations. Access must be provided for equipement to conduct weed control or other critical crop management practices. Excess water may prevent access. Drainage is less important after a plantation is free to grow. An established plantation consumes a significant quantity of water and may dry the sites.

- Subsoiling

Compact soils aggravate the drainage problem. Subsoiling provides internal drainage, aeration and greater soil depth. This operation can be done using a ripper blade pulled by a D-8 caterpillar tractor.

- Fertilization

Fertilizers are very expensive and their application will probably not be economical. Research must be conducted for each managed site in order to define limiting nutrients and identify in the region sources of cheap fertilizers such as waste from industrial processes (pulp and paper mills, textile mills,...). Legumes or plants fixing nitrogen such as alder could also be planted alternatively with trees. This biological method is also used to control weeds.

5.3.2- Description of interactions

Generally speaking, potential interactions between SRIC activities and selected species of terrestrial life forms will be a direct loss of habitat and species of terrestrial - aquatic and aquatic habitats might be affected by a modification of water quality resulting from the intensive spray of herbicide and chemical used to site preparation, weed control and fertilization. The man-made plantation might also be very attractive to rodents, hare and other browsers that damage planted trees.

INTERACTIONS WITH TERRESTRIAL LIFE FORMS (1.1 TO 2.8)

Species relevant to mature forest (grouse, squirrel, marten, owls, hawks) will definitively be affected as large pieces of land will never reach the maturity stage important for reproduction, feeding, shelter and escape cover.

Species of life forms 2.1 to 2.8 of immature forests, marginal farmlands, fields, meadows, alpine meadows and various forest types would likely interfere with these plantations. Site preparation (mechanical and/or chemical could have the same effect on wildlife than on plant communities: complete destruction and eradication of species. The effects could be direct on small mammals (voles, badger,...) and reptiles (snakes, lizard, racer,...) and indirect on raptors (hawks, falcon, eagle, owls) by a reduction of key prey species. Matsumara *et al.* (1972) stated that in labor-saving reforestation programs, Amitral and 2-4-5-T were introduced as bush killers. Over-all application of herbicides in reforested areas deprived wildlife of food. Matsumara *et al.* (1972) also stated that simazine can be used continuously at recommended rates without deleterious effects on litter soil or crops. They also stated that there is no consistent evidence indicating that animals and soil micro-organisms are capable of cleaving the atrazine ring at a significant rate. Very little 5-triazine residues seem to be retained in animal tissue after ingestion of potent 5-triazine compounds or their soluble and insoluble plant metabolides. The acute oral toxicity of three herbicides used in energy plantation are 5 000 mg/kg for simazine, 3 080 mg/kg for atrazine and 3 400 mg/kg for diuron. Matsumara *et al.* (1972) also stated that these herbicides are much less persistent than the organo-chlorine insecticides: most of them have a much lower mammalion toxicity and they are not usually concentrated in biological material. Most organic herbicides break down rapidly in soil, although some, such as atrazine and diuron, may persist for a year or longer in soil. The most persistant herbicides is simazine. In general, these herbicides do not seem to be very hazardeous to wild animals, although their indiscreminate use may destroy many natural habitats.

Most species of these life forms (2.1 to 2.6) reproduce on or under the ground. Burrowing species (badger, burrowing owl,...) will be severely affected by mechanical site preparation and other activities as machinery to spray herbicides, fertilizers and harvesters. Bunnell and Eastman (1976) stated that severe site disturbance by mechanical means reduces the amount and productivity of wildlife habitat. Herbivores of these life forms (moose, deer, elk, grouse, ptarmigan, pheasant, chipmunk) will loose these treated areas as supply of forage and seeds as all vegetation will be eradicated. Carnivores (coyote, fox, falcon, hawk, lizard, snakes) will have a short-term advantage by the reduction of escape cover of prey. On a medium term, prey will be absent from treated areas which will become desert for both groups of species.

As planting will shortly follow site preparation, it is predicted that wildlife will gradually re-occupy the site beginning with small mammals and followed by larger predators and browsers. The overall wildlife activity should depend on the size of plantation and proximity of natural forest or undisturbed habitats. As no data are available to predict interactions, it could be predicted that planted and fertilized trees will represent an excellent source of food for rodents (voles, mice, shrews, hares). These effects have already been noted in the Fraser valley of British Columbia where 50 to 80% of an experimental plantation was destroyed by voles (Smith and Blom, 1966). Losses as high as 95 to 99% of plantation grown trees due to rodent activity have been recorded by Moore (1940), Eade (1954), and von Althen (1971). Radvanyi (1977) noted that many of the young trees of a hardwood plantation had been girdled and killed by the rodent population living on an area of abandonned farmland near Toronto, Ontario. Near Parkhill, Ontario, another tree plantation on which rodents had been encountered and on which small mammals populations studies were also conducted during the summer 1972. Populations of at least 82 animals per hectare were noted. These included Microtus pennsylvanicus (78,3%), Sorex cinereus (10,3%), Peromyscus maniculatus (6,4%) and Blarina brevicauda (5,0%).

Impact of SRIC concept on ungulates would be the reduction of the availability of winter cover due to poorer snow-catching ability of short, often deciduous stands (Telfer, 1978). Damages by browsers could be acute when added to that by hares. Ungulates feed preferentially on fertilized exotics. Where cover is available, it is predicted that damage by ungulates will be limited to the perimeter of planted site and to a distance of approximately 100 m into plantation. Damage can be expected until planted trees grow enough to impede ungulate movement. Hares, mice, shrews and voles might however find greater protection within the plantation as access for larger predators would be limited.

Species requiring open areas (meadows, field,...) should be locally affected by these plantations: reduction of habitat either for reproduction, cover and shelter (badger, lizards, snakes) or for hunting food (owls, eagles, falcons, hawks, reptiles,...). The Burrowing Owl is a typical example of species that have suffered from ranching and farming in the Prairie Provinces and British Columbia. The known and possible factors causing decline of the species (Wedgwood, 1978) are:

- loss of open short grass by cultivation, urban development, orchards, road construction, land flooding;
- loss of nest burrows by eradication of burrowing mammals (badger, prairie dog,...);

- destruction of burrows along pasture improvement practices aiming to either fill in badger holes or plow up native pastures;
- chemical contamination by pesticides (e.g. deildrin) and rodenticides;
- shooting that appears to be more widespread than had been supposed;
- road kill while chasing insects attracted to a road still warm from the day's sun;
- predators such as Swainson's Hawk, bull snakes, badgers, skunk, weasel, foxes and large owl.

Loss of habitat, loss of prey, contamination with chemicals and harassment appear to be the most significant threats for species inhabiting meadows, pasture and requiring logged areas for hunting.

Not much can be said about reptiles (lizard, racer, snake) of life form 2.4. Many of these species are encountered in southern Québec and Ontario where energy plantations are likely to be undertaken first. These areas of marginal farmlands and forests are within the northern limit of distribution of many species and loss of critical habitats could reduce populations which are already affected by agricultural practices.

INTERACTIONS WITH TERRESTRIAL - AQUATIC LIFE FORMS (3.1 TO 3.5)

Species both requiring terrestrial and aquatic habitats for reproduction, shelter, feeding requirements should be similarly affected than with agriculture when cultures are done on marginal farmland. On logged areas, loss of habitat is only predicted where culture will be undertaken in riparian zone or on upland sites near waterbodies. As most of the effects will be similar than for the Complete Forest Concept it is not discussed here. However, chemicals used for site preparation, weed and pest or rodent control can modify water quality and interfere with species feeding in water (either herbivores and carnivores).

Land drainage to permit a better growth of fast growing trees and to allow machinery circulation might represent a threat for ground nesting waterfowl, reptiles and amphibians in the surrounding of plantation site. This problem is already acute from agricultural practices. Bellrose (1976) reported that almost 1,21 million hectares have been drained in the Prairie Provinces. In southern Ontario, of the 4 330 ha of prime marshes formerly located along the north shore of Lake Ontario, only 1 025 ha remain. Also in Ontario, an estimated 50% of the original wetlands have been lost in the area south of Lake Simcoe (Mosquin and Suchal, 1977). As planted trees require much water to grow, it is predicted that within areas selected for intensive culture, wetlands will be drained to raise the amount of managed land close to mill sites. Drainage for this purpose will however be light in order to keep enough water to optimize tree growth.

Flooding from beaver dams can also damage plantation if done in a potential flooding zone.

5.3.3- Mitigatives measures and general recommendations

As the Energy Plantation Concept has not yet been implemented on a large scale, mitigative measures, as well as interactions, can only be predicted.

The most important mitigative measure is a good impact study to help planners choose the best mill site and associated plantations within a given region. This study should include all biophysical, socio-economical and cultural features. Wildlife should be analyzed in order to first define species and population within a study area comprising all lands suitable for SRIC. Population census compared to a biophysical classification of the study area should stress the most valuable habitats for wildlife. Simulation of all activities related to SRIC on wildlife habitats will define sensitive areas that should be protected and sensitive areas where mitigative measures must be applied.

For species of life forms 1.1 to 1.8 (grouse, squirrel, owls,...) present in the study area, blocks of mature forests, immature and young forests should be retained from conversion to SRIC. All age classes should be preserved so wildlife of mature forests can always find suitable habitats. Proportion of these forests would vary with species involved.

Species of life forms 2.1, 2.2, 2.5 and 2.6 (moose, deer, weasel, falcon, bear, cougar,...) would also benefit from retaining various age forests from SRIC. Amount of land reserved should be defined in accordance with recreationnal characteristics of the zone for game species and in accordance with the given status of rare, threatened and endangered species within the area studied. For instance, a buffer zone should be kept intact in areas of high potential for raptors especially if Peregrine Falcon are in the area. These lands would not only serve wildlife purposes but could also reduce damage to plantations by small mammals (mice, shrews, hares, voles,...) and insects. In large plantations, where girdling is observed, poisoning, trapping and other control measures described previously (5.2.4.3) could be applied. Another possible biological control measure is to install perches for predators (raptors) within the plantation. Efficiency of such a measure is however not proven.

Species of life forms 2.4 and 2.5 (Badger, Burrowing Owl, Prairie Falcon, lizard, racers, snakes,...) would likely be the most affected species as energy plantations are favoured in marginal farmlands, meadows and logged areas imperfectly drained. Special attention should be given to rare, threatened and endangered species. For instance, reptiles of life form 2.4, all rare or threatened species, are mostly found in southern provinces where SRIC should be undertaken first. Studies should be undertaken to assess potential impacts starting with basic study of species, population size and related habitats where these species are encountered. Sensitive areas should be mapped and publicized to all promoters and mitigative measures should be developped. Also promoters should ensure that part of the marginal farmland and meadows should be retained from SRIC. Retained fields, meadows and logged areas would so be utilized by predators for hunting. These sites should be interspersed within the study area to provide equal access to key prey species. It should not be forgotten that in any management activity, diversity is the most effective measure to avoid problems.

Land drainage to increase amount of land suitable for Energy Plantations should be well analyzed in order to prevent damage to wetlands and riparian zones used by wildlife species of life forms 3.1 to 3.5. If water table is lowered at a definite spot, effects can extend to other surrounding lands. Analysis of the hydrologic features of the area should preceed any land drainage and should be avoided or mitigated when damage to high potential waterfowl habitat is detected. Also, to prevent siltation, increased turbidity and temperature, buffer strips and other measures described previously (5.2.3.3) should be applied. All chemicals applied on the lands should be approved by specific authority and a monitoring of main watercourses should be done before and after treatments. A survey of all potential herbicides and fertilizers should first be done and effects on wildlife and water quality should be clearly expressed and publicized to all promoters.

As Energy Plantations could soon become operationnal, a pilot impact study should be undertaken in an area of marginal farmlands, in a mixed marginal farmland - logged area and in a logged area to serve as illustration when this concept will be implemented on a large scale.

5.4- Production of native species on short rotation

5.4.1- Description of activities

As described previously (3.2.3), there are no actual surveys of this latter alternative, simple management activities for this source of forest biomass will be considered which could be extrapolated to all sites that are suitable for short rotation: disturbed sites, unimproved agricultural lands, logged areas fully restocked with undesirable species, powerline right-of-way, natural high yield shrub and trees areas (alder, willow,...). Activities related to this alternative should generally follow similar patterns:

- clearcutting undesirable, immature and low class mature stands to be used for energy conversion
- stimulation of root-suckering, sprouting and seeding to ensure abundant regeneration
- planting when necessary
- fertilizing
- harvesting or coppicing on a short rotation basis (less than 40 years).

Results of a Finnish research study (Hakkila et al., 1979) showed that biomass available from wild stands could be used for several decades before special biomass plantations might be economically justifiable (Smith, 1979).

5.4.2- Description of interactions

Potential effects of the Production of Native species on Short Rotation on wildlife of concern are difficult to assess as first this concept is not well studied and machinery and practices are not yet developped. However, some effects on terrestrial life forms can be predicted.

Life forms 1.1 to 1.8

As short rotation management would maintain native tree and shrub species that thrive in early succesionnal stages, animals preferring late-successionnal trees would thus be adversely affected (Telfer, 1978). Effects on these species (marten, lynx, fisher, owl) could be similar to other practices that involve a reduction of rotation length (silvicultural practices and SRIC).

Life forms 2.1 to 2.8

Effects on ungulates of such practices can be either positive or negative. When managed trees of shrubs are preferred by animals, it is predicted that more browse will be available for ungulates. However, the crown layer of these intensively managed stands might have limited ability to catch and hold snow thus reducing winter cover availability.

Effects on small mammals could also be positive for some species that thrive in early successionnal stages (mice, voles, shrews, hares). Coppicing every 20 to 40 years might favor high population of few species and on a medium term damage managed sites. The high density of managed stands might impede predators reaching prey either from the air (owl, eagle, falcon,...) or on the ground (fox, coyote, cougar).

5.4.3- Mitigative measures and general recommendations

Mitigative measures to attenuate negative effects and increase positive effects on wildlife will first necessitate a complete understanding of actual species and population encountered in the areas managed. As this alternative will be undertaken as well on natural poplar stands and stands made of undesirable species for actual market conditions, comprehensive studies should be undertaken to get more basic data about the importance of these stands for wildlife. Under an ENFOR project, a comparative study is under way near Rimbey, Alberta, to determine the effects of short (30 year) rotation harvesting of aspen on wildlife. Habitat quality and use by wildlife is being investigated in 10 - 15 year old stands, 30 year old stands and mature stands (over 60 years old). The study includes an inventory of forest stand composition and browse production as well as comparative studies of use by avifauna and ungulates (Westworth, 1981). Similar studies should be extended to other parts of the country and to other tree and shrub species suitable for short rotation (paper birch, willow, larch, alder, maple, jack pine, fir,...).

In order to minimize potential damage and optimize habitat for wildlife, this alternative should be implemented among other forestry or agricultural activities thus creating a mosaic pattern of opened, young, immature and mature stands which will favour diversity and favour wildlife.

6.- SYNTHESIS OF RECOMMENDATIONS

This last part of the report aims to apply general recommendations stated previously to the specific context of provinces or group of provinces. To reach this objective, most pertinent management alternatives will be compared to the most problematic wildlife species.

6.1- Complete Forest Concept

6.1.1- Road construction and use

Studies that could be undertaken in most provinces could be divided in two types depending if it concerns new territories to be developped or if it concerns roads already built and used.

In British Columbia, Prairie and Central provinces and Newfoundland, forest companies are still building roads to reach untouched forest lands. For these areas it appeared important to:

- Define wildlife harvest policy before roads are built. This study should analyse comparatively 2 cutting sectors where a forest road will be built. In both sectors, a survey of terrestrial, semi-aquatic and aquatic wildlife species should be conducted before road construction. For one sector, wildlife harvest policy will be defined and hunting and fishing regulations elaborated and applied. A monitoring of both sectors should then be conducted after construction and every three to five years while operating the road. Results should stress the importance of defining hunting and fishing regulation before and not after wildlife resources have been depleted by these activities.

- Overall survey of fish habitat in the Green Area. This study should be conducted in order to establish the sensitivity of lakes, rivers and streams (fish habitat) to various forest operations. 1:125 000 or 1:250 000 maps should be prepared first using information already available and second doing fieldwork in areas where roads are going to be built. Such a document will be very helpful to planners and should highly contribute to prevent damage to aquatic habitats.

- Public Education Program. Enhancement of public education programs and increase public awareness to reduce harassment and often kill on sight sensitive species (cougar, lynx, raptors, owls, reptiles,...).

In Central and Southern part of most provinces, road systems already used should be checked in order to:

- Assess the efficiency of bridges and culverts and the work to be undertaken to restore fish movement especially in small streams. Results from such a study within two or three sample regions will demonstrate the importance of extending such initiative to all roads systems.

- Evaluate the efficiency of forest road closure as a management tool to limit harassment on wildlife by recreationnists and hunters. Some authors have noted that closed roads are more preferred than open roads by hunters.

- Eliminate road duplication within the Green Area. This study should be enhanced in different forest regions where the road system is highly developped and where road system is going to be developped. Analysis of road system location (grade, operating cost, actual and future level of operation,...) compared to the capability of land for wildlife, recreation, forestry within sampled areas should demonstrate some real benefits - lower cost, less and taken out of timber production, less environmental damage and less harassment of game. More information of such study is available from the Environmental Council of Alberta in Edmonton.

6.1.2- Forest biomass extraction and silvicultural practices

Effects of Complete Forest Biomass Removal on ungulates

Complete removal of forest biomass can be detrimental to ungulates (moose, elk, deer,...). The regeneration following treatment will generally produce a positive effect since the amount of available food will be increased. However, very large cut areas are not much used by moose until a new stand becomes well established (Telfer, 1974). This author stated that much of the effect on wildlife from logging depends on the pattern produced (including size and shape of cut areas, location and species composition of uncut stands). Dryade (1980) stated that there are probably five direct major source impeding regeneration to develop after complete removal of forest biomass:

- Decrease of soil moisture
- Increase soil temperature
- Removal of all trees and shrubs
- Reduction or diminution of organic top soil
- Reduction of soil fertility

Studies should be undertaken to evaluate the effect of complete removal of forest biomass on the quality and quantity of regeneration available for ungulates. Variables that should be analyzed are: regenerating time of vegetation, diversity of regenerated stands in relation with the size of cutovers, type of machinery, season of operation.

Studies should also be undertaken in order to evaluate the validity of the literature recommendations related to the size and shape of cutovers. Authors recommend small patch clearcut as a management tool for ungulates. However, most of the recommendations are based on local observations of ungulates behaviour and have not been subjected to experimental tests. Monitoring of areas cut (including residues and unmerchantable trees and shrubs) should be done for each species of ungulates in high density areas. The use of residues should also be analysed and specific recommendations should be made to optimize ungulate production (deer, moose, elk, caribou) or to protect managed forests (plantation) from overbrowsing.

In intensive managed forests, information about harassment stimuli in terms relevant to animal perception and definition of animal responses to harassment sources should also be gathered and recommendations should be developed and distributed to wildlife and forest managers.

In highly managed forests, winter range for ungulates should be indentified, mapped and published to sensitize forest planners, operators and woodlot owners to the importance of these critical habitats and how to manage these forests to ensure their long term sheltering capabilities.

All these data should be used on an experimental basis to prepare a long term management plan that will provide suitable habitat (forage, winter range,...) that will optimize both ungulates and wood production. Long term management plan means at least two or three rotations. Simulated models such as FORCYTE 11 (Kimmins *et al.*, 1982) should also include wildlife considerations.

Effects of removing all residues from treated stands on wildlife

Removing all residues from logged areas also imply the extraction of all unmerchantable trees and shrubs and all down woody material and snags. These types of residues represent primary habitat for many wildlife species including small mammals, larger carnivores and birds.

The absence of residues can generate two direct effects: reduction of shelter against predator and lack of food at short term. The character, density and distribution of logging debris may significantly affect both the number and species of vertebrate animals that use a site. Thus logs are considered to be more important as wildlife habitat than any other form of woody debris (Thomas, 1979). This author stated that when logs are lacking, some windrows, slash piles and root wads should be kept to simulate log habitats.

Studies should be enhanced to evaluate small mammals population changes after removing all biomass from treated stands; to analyse the ecological niche of these species and to evaluate the optimal amount and quality of residues necessary to ensure viable populations.

Many specialists see a direct relationship between the number of snags and the number of snag-dependant wildlife in forest. So, a primary cavity excavator, such as the woodpecker, must first dig a hole. As marten is a secondary cavity user of snags, removal of such material thus affects directly marten, since it lost the dens cavity and indirectly by the loss of primary excavator. The size and height of snags also determine which species will use a snag for nesting. Snags must be well distributed to be most effective in the number of pairs of cavity-nesting birds they will support because of the territorial requirements of the primary excavators. The management level is a function of the amount of forest area containing snags and the number of snags present. To protect nesting and breeding sites of many mammals and birds, the evaluation of the importance, quality and quantity of different types of snags within the Canadian forest regions is essential and is the basis to prepare option of wildlife management guidelines. These studies should establish the relations between number and quality of snags (height, diameter, species, decomposition stage), the use by primary cavity excavator (woodpecker) and other snag-dependant species. Results of these studies should permit recommendations of measures to conserve optimal quantity of snags within cutovers that will ensure on a short-term basis protection of suitable nesting sites for wildlife.

In order to foresee the use of snags by wildlife on a medium or long term basis, study should also include the lifetime of a snag. Snags come and go throughout the life of a stand. For example, if a ponderosa pine stand is clearcut and enough snags are left to provide for 100% of the potential population of all woodpeckers, this snag level will be maintained only until the snags begin to deteriorate. Careful management will be required to provide snags of sufficient size to ensure the long-term welfare of dependant wildlife species. A number of methods can be used by the forest manager to produce snags: long rotation of either stands or selected trees, killing of suitable trees and retention of snags in managed stands (Thomas, 1979).

Effects of forest biomass extraction on nocturnal raptors (Great Gray Owl, Long-eared Owl, Boreal Owl and Hawk Owl)

Effects of forest biomass extraction on avifauna are mainly related to the size of area treated, the season of operation and the type of material harvested. Nocturnal raptors will be affected by the reduction of nesting site availability. The Long-eared Owl, for instance, generally nests in old nests of crows; the Great Gray Owl also nests in trees and availability of nests, again is probably the most important limiting factor. Many studies should be undertaken within the range of these birds to:

- estimate the present day population of these rare or endangered birds;
- determine the status of local populations of the Great Gray Owl;
- determine whether these birds breed in Québec and other areas, where birds have been seen in summer, but where there is still no nesting evidence;

- evaluate preferred habitats for Great Gray Owl across the range to establish the effect of forestry practices, forest biomass extraction and other factors affecting boreal forests;
- identify protective measures for nests, for key prey species from nest destruction and disturbance of nocturnal raptors;
- evaluate the effects of human disturbance and associated noise on the nesting habits of nocturnal raptors;
- prepare guidelines to reduce habitat destruction and general disturbance of birds;
- monitor small mammals fluctuations after removal of all biomass from treated stands in areas of high bird density.

Effects of forestry practices on Peregrine Falcon

As Peregrine Falcons are highly sensitive to human disturbance, intensive forest management would also be detrimental to this species. Although some research have been done on Peregrine Falcon, no study is specific to forest management and logging activities. All known information (range, known nests location, behaviour, response to human disturbance) should be first analyzed. Experimental tests to specify the response of Peregrine Falcons to logging activities and silvicultural practices should be made to develop appropriate mitigative measures. All the gathered information should be distributed to forest managers and operators within areas where populations of this species exist.

Since herbicides, rodenticides and insecticides were the major cause of Peregrine decline, development of new pesticides or phytocides to be used on plantations or for silvicultural treatments should be monitored closely to establish their effects on sensitive wildlife.

Guidelines for the protection of other rare and endangered species

Effects of forestry practices are difficult to assess for species such as cougar, lynx, bears, wolf, raptors and reptiles. However, specific measures to protect prey and ensure diversified habitats could only be beneficial. As most of these animals are naturally rare and range over large areas, guidelines should be prepared to protect animals from harassment and destruction of habitats. These guidelines should be publicized to all forest workers and visitors urging them, for instance, not to shoot, harass, or disturb these animals.

Evaluation of the effects of intensive forest management on rare vascular plants

Vascular plants should also be considered as an integral part of forest ecosystems and be respected while managing forests.

Lists of rare vascular plants elaborated in each province by the Museum of Natural Sciences permit the separation of species encountered in forests and associated habitats (thicket, clearing, lake, river and stream sides, marsh and bog) from non-forest species. Further analysis of data will necessitate more information about ecology, distribution and sensitivity of plants to forestry activities.

A first study should pin-point species that are threatened or endangered, permitting the location and protection from disturbance of typical areas where they are still present. This aspect is usually undertaken by provincial governments while creating ecological reserves where human activities are restricted.

A second study should consider all other rare plants in order to ensure their presence within managed forests. A pilot study should be made within a region where forests are intensively managed and where rare plant species are numerous. Objective of such a study would be to translate botanical data into the language of forest management. From the actual listings available at the Museum of Natural Sciences in Ottawa, a listing of plants that are possibly present within a study area should be prepared.

Analysis of the ecology of these plants should determine location of potential habitats. A survey of these habitats should determine exact location and amount of critical species and habitats. Mapping of these habitats compared to forestry data and management plans would identify areas that should be protected or carefully managed. Results from such a study would stress the importance of considering rare plants in forest management and define a working method that could be applied to other managed forests. Southern British Columbia, the southern parts of Central Povinces and Atlantic provinces contain numerous managed and unmanaged forests where this study can be undertaken. A close collaboration with the Museum of Natural Sciences will be useful in choosing the study area, elaborating regional listing and understanding the ecology of selected species.

Monitoring of the efficiency of buffer strips on water quality

Buffer strips of varying widths are usually recommended to protect cold water fish habitats from heating, siltation, erosion and turbidity. These strips appear to be sufficient as most of the provinces recommend such measures. However, few basic studies demonstrate their efficiency. Under the Complete Forest Concept, these strips will become more and more attractive to logging operators as they often contain large volumes of wood.

Studies should be undertaken to assess the efficiency of green belts for different categories of streams, rivers or lakes and diverse slopes, surficial deposits and position of the waterbody within the watersheds.

Rating and mapping watershed basins for relative sensitivity to various forest practices and operations

It is admitted by authors that removing trees modifies water production and possibly water quality produced by a watershed. Studies should be initiated to rate and map watershed basins for relative sensitivity to various practices and operations. Such studies would have to take into consideration factors such as the size of watershed, type of surficial deposits, slopes, precipitations, logging methods and type of machinery, season of operations, proportions and location of areas cut,... On the basis of these evaluations, changes in the ground rules may be desirable to maintain the production of clear, clean and cold water and so protect fish habitats from destructive modifications.

Effects of forestry practices on reptiles and amphibians

Reptiles and amphibians are the most poorly documented group of wildlife species of this study. In many provinces, three conflicts with reptiles have been identified: loss of habitat, destruction of denning sites and a tendancy of many people to kill these animals on sight.

In British Columbia, the loss of suitable habitats appears as the most significant conflict with amphibians, although logging practices are also stated as an important source of conflicts. Furthermore, many people have a negative attitude towards frogs and salamanders and some will kill them on sight.

Intensified forest management can therefore increase conflicts with these animals. To prevent harassment, loss of habitat and killing, it is recommended to enhance studies to:

- specify what types of habitats are susceptible of being affected by complete biomass harvesting;
- confirm the status of species considered as rare, threatened or endangered and, if needed, to intensify research on species having an undetermined status;
- evaluate the minimal amount of down woody material to ensure viable population of amphibians and reptiles;
- verify if buffer strips size proposed to protect riparian and aquatic habitats are sufficient to also protect amphibians and reptiles using similar habitats.

Rare, threatened and endangered fishes

Many fishes are being considered rare or endangered: Shorthead sculpin, Aurora trout, Redside dace, Blueback herring, Blackfin Cisco, Round Whitefish, Cutlips minnow, Speckled dace,.... As their range and biology are largely unknown, research should be undertaken to locate the distribution and main waterbodies where these species are encountered, to establish the limiting factors associated with forestry practices and causes of decline when known and to identify protective measures that will ensure their survival. All this information should be publicized in areas where many of these fishes are encountered.

Public educational program

As the Complete Forest Concept will become sooner or later a common practice, assessment of forest management-wildlife relationships should be made in order to prepare educationnal material (films, pamphlets,...) to sensitize the general public to the detrimental and beneficial effects of clearcutting mature stands, silvicultural practices for forest renewal, the impact of human presence and to the importance of snags, logs and other residues as habitats for wildlife.

British Columbia

Effects of Complete Forest Concept on woodland caribou

Impact of complete forest biomass extraction on wildlife of late successionnal stage forests appeared to be very detrimental. Of all species considered here, woodland caribou is one of the most sensitive species. Addison (1980) has noted a high competition between logging and caribou for mature stands of high-elevation timber. In the winter, arboreal lichens become the dominant food source as forage items. The ecology of arboreal lichens is presently one of the most poorly understood components of caribou habitat (Addison, 1980). There is general agreement that the most important factors are the following:

- tree age
- tree species
- stand density
- moisture conditions

One of the most critical information gap, because of its implications for the carrying capacity of caribou winter range, is the lack of even the crudest data on lichen growth rates (Addison, 1980). It is recommended to:

- assess lichen growth rates in relation with different forest types (tree age, tree species, stand density), moisture conditions, elevation within woodland caribou winter range;
- analyze the effects of cutting methods on arboreal lichen production and availability;
- evaluate the influence of the removal of lichen-bearing snags on dispersion of lichen in woodland caribou winter range;
- analyze the slash disposal methods and their efficiency as temporary food supply (impeding or favouring game movement).

Addison furthermore stated that there is a considerable degree of uncertainty in caribou management that must be considered in the evaluation of options and in attributing specific positive and negative impacts to them. Substantial information gaps exist in the areas of:

- seasonal caribou distribution and habitat use patterns;
- the major migration corridors;
- lichen/forest site relationships.

Studies aiming to complete information gaps should be enhanced to predict the effects of harvesting on these components.

Concerning stand regeneration and silvicultural practices, Addison (1977) also indicated that much remains to be learned about the effects of second-growth management on arboreal lichen production.

These studies should be conducted within the range of woodland caribou in high elevation forests of Alberta and British Columbia. Finally, the possibility of retaining areas from development or hunting activity should be seriously considered within these zones.

Effects of Complete Forest Concept of Grizzly bear

Intensive forest management and forest biomass extraction in wilderness areas will increase man-bear conflicts where logging activities are intensive, loss of cover would make bears more accessible to hunters. Important Grizzly range areas should be restricted first to limit conflicts and second to avoid over-killing of the species.

Before these limitations are applied, studies should be initiated to gather information on the ecology and population dynamics of grizzlies in the coastal region of British Columbia and within the boreal forest in Alberta and British Columbia.

Also, it is recommended by authors to identify and map critical habitats of grizzly in order to evaluate precautions to minimize conflicts while managing forests. Landstat imagery could be a useful aid for such a mapping.

Finally, co-operation and coordination between federal and provincial agencies responsible and industries for wildlife management, land-use planning and resource development be encouraged to control and minimize the effects of forestry developments into grizzly ranges.

Effects of forestry activities on Vancouver Island marmot

In order to prevent harassment and habitat destruction, studies should be undertaken to identify and map potential habitat of the Vancouver Island marmot. Furthermore, population census must be made before development of new territoiries within the defined critical habitat and areas utilized by the marmots should be retained from human activities.

Prairie Provinces

Protection of White Pelican, Whooping Crane and Double-crested Cormorant

Loss of habitat, harassment, disturbance and shooting appeared to be the main factors of the decline of these species. Inventory and mapping of critical known habitats and migration corridors should be done and publicized to all potential users as well as all pertinent information about these threatened or endangered birds.

Central Provinces

Effects of forestry practices on Kirtland's Warbler

Kirtland's Warbler is the most endangered bird in Canada. It is restricted to young jack pine forests of south-central and southern Ontario. These forests, because of intensive fire protection and management objectives are slowly disappearing. Regeneration of suitable habitat is essential for the protection of this bird.

Studies should aim at understanding the biology of the bird population in Canada and second to define areas where cutting mature forests should be done to regenerate suitable habitat.

Atlantic Provinces

Effects of forestry practices on the Newfoundland race of American marten

Considered as an arboreal species, marten is a typical secondary snags user. Snags are used as dens or as resting or escape cover.

Removal of snags affect marten directly, since it lost the den cavities indirectly by the loss of primary cavity excavators.

As it is predicted that forest biomass extraction will increase in the coming decades, efforts to re-establish viable marten populations in other suitable sections of the island should be continued, especially where timber harvest is unlikely to occur and where human access is limited. More information could be obtained from the Newfoundland Wildlife Division.

Inventory and testing of control measures to limit porcupine damage in Eastern Provinces

As porcupine damage is common in Eastern provinces and as no effective methods of controlling population has been successful, a study is recommended to develop and test measures to control populations. If measures such as trapping, shooting or poisoning are not successful, behaviour of porcupine should be analyzed to relate, for instance, thinning intensity to potential damage by this animal. In fact, porcupine damage occur mainly on young 10 to 30 or 40 year-old coniferous trees when thinning gives the best result.

6.2- The Short Rotation Intensive Culture

As the Energy Plantation Concept has not yet been implemented on a large scale, recommendations of studies are quite limited. A possible avenue of work will be to analyze the actual hypothesis and experimental plantations to develop guidelines that could be publicized to promoters when this concept is implemented on a larger scale.

Pilot impact study on the effects of SRIC concept on wildlife and other environmental components

Within the areas suitable for energy production (see figure 4, p. 27), pilot impact studies should be undertaken in an area of marginal farmlands (e.g.: south-central Ontario, southern

Québec or in the Maritimes), on a mixed marginal farmland - logged areas and in a logged area. These pilot impact studies should be done to serve as illustration for future developments.

These studies should include every step of a typical impact study which usually includes:

- Objective of the project (ethanol, methanol, power generation,...)
- Description of the project
  - technical characteristics
  - location
  - schedule of work
- Description of the area covered by the project
  - soil
  - vegetation
  - wildlife
  - water
  - human aspects
- Location of possible mill sites and associated lands to produce raw material
- Identification and evaluation of impacts of possible alternatives
- Choice of a mill site and associated lands to produce raw material
- Mitigative measures and residual impacts
- Monitoring of mitigative measures and residual impacts

Evaluation of the impacts of SRIC on wildlife

As some areas in southern-central Ontario are now or will be planted with fast-growers such as hybrid poplars, much of the predicted effects could be checked to substantiate basic data of potential interactions with wildlife and other environmental components. Specific aspects should be analyzed:

- Effects of intensive application of herbicides on aquatic, riparian and terrestrial habitats;
- Effects of application of fertilizers, especially when sludge from paper or textile industries will be used as cheap fertilizers, on riparian and aquatic habitats;
- Effects of large and numerous plantations within a given region (e.g.: south-central Ontario) on recreational, rare, threatened and endangered species;
- Evaluation of damages by wildlife in plantations already established in south-central Ontario;
- Evaluation of potential impacts on reptiles and amphibians population of southern Ontario and Québec.

CONCLUSION

This report presents an overview of existing knowledge of interactions between maximum forest biomass production and wildlife in Canada. This management concept implies the construction of more access roads to remaining untouched forests, the cutting of these mature and overmature stands (including the removal of all forest residues), intensive management of second-growth forests and techniques required to produce maximum volumes on short-rotation basis (biomass farming). Wildlife has been analyzed considering rare, threatened, endangered, recreational species and animals that are likely damaging trees.

All the information contained in this report comes from available literature and unpublished information gathered in each province of Canada. As the subject was extremely wide, we believe that interactions defined and studies recommended only cover part of the problems. Much more dialogue and studies will be necessary to obtain complete knowledge of interactions. We only hope that our work will help land managers and public to understand the importance of considering wildlife as an integral part of forest management.

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Appendlice I
Consulted agencies

British Columbia

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Victoria

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Prairie Provinces (cont'd)

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Central Provinces

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Atlantic Provinces

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Appendice II
Rare vascular plants

Atlantic provinces - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
	N.B.	N.S.	Nfld.	Forest	Wet forest	Thicket	Clearing	Stream, river	Lake	Marsh	Peat-bog
Acalypha rhomboidea Raf.	x			x							
Adiantum pedatum L. var. pedatum	x	x		x							
Agrimonia gryposepala Wallr.	x			x		x					
Allium tricoccum Ait.		x		x							
Alnus serrulata		x			x						
Anemone Quinquefolia L. var. quinquefolia		x						x			
Angelica atropurpurea L.			x			x					x
Antennaria parlinii Fern.		x		x							
Antennaria plantaginifolia (L.) Hook.	x			x							
Aretagrostis arundinacea (trin.) Beal var. crossispica Bowden			x	x							
Arenaria macrophylla Hook			x	x							
Aster acuminatus Michx.			x	x	x		x				
Aster laevis L.	x			x							
Aster undulatus L.		x		x		x					
Athyrium alpestre var. americanum (Butters) Boivin			x	x							
Botrychium dissectum Spreng.	x			x		x	x				
Botrychium lanceolatum (Gmel) Angstr.	x	x	x	x	x						
Botrychium multifidum (Bmel) Rupr.			x	x		x					
Botrychium virginianum (L.) Sw			x	x	x	x	x				
Calypso bulbosa (L.) Oakes var. americana	x		x	x	x						x
Cardamine parviflora L. var. arenicola (Britt) Schulz	x			x							
Carex adusta Boott.	x			x							
Carex albolutescens Schw.	x				x	x					
Carex amphibola Steud. var. turgida Fern.	x			x							
Carex arcta Boott	x				x						
Carex backii Boott	x			x							
Carex bromoides Schkuhr		x			x						x
Carex capillaris L.	x			x	x	x	x				
Carex castanea Wahlenb	x			x		x	x				
Carex concinna R. Br.	x			x							
Carex convoluta Mack.	x			x		x					
Carex crinita Lam. var. simulans Fern.		x		x	x						x

Forest Wet forest Thicket Clearing Stream, river

Lake Marsh Peat-bog

Atlantic provinces - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
	N.B.	N.S.	Nfld.	↑	↥	↑↑↑	ꟷ	→	⊂→	≈	⩚
Carex hirtifolia Mack.	x			x							
Carex howei Mackenz.	x			x		x					
Carex laxiflora lLam. var. laxiflora		x		x							
Carex leptonervia Fern.			x		x	x					
Carex lupulina Muhl.	x				x						
Carex media R. Br.	x										x
Carex pedunculata Muhl.		x		x		x					
Carex pensylvanica Lam. var. distans Peck.	x			x		x					
Carex plantaginea Lam.	x	x		x							
Carex praticola Rydb.			x	x							
Carex spaganioides Muhl. var. cephaloides (Dew.) Carey	x			x							
Carex sprengelii Dewey	x			x							
Carex swanii (Fern.) Mack.	x			x		x					
Carex tuckermanii Boott.	x	x		x		x					
Caulophyllum thalictroides (L.) Michx.	x	x		x		x					
Celastrus scandens	x			x							
Chimaphila umbellata (L.) Barton			x	x							
Claytonia caroliniana Michx.			x	x		x					
Clethra alnifolia L.		x			x				x		
Coeloglossum viride (L.) Hartmann spp. bracteatum (Muhl.) Hult.		x			x						
Conopholis americana (L.) Wallr.		x		x							
Conioselinum chinense (L.) Bsp.			x		x	x					
Cornus alternifolia L.			x	x							
Cryptotaenia canadensis (L.) Dc.	x			x							
Cynoglossum boreale Fern.	x	x		x		x					
Cypripedium arietinum R. Br.		x		x		x					
Cypripedium calceolus L.		x		x							
Cypripedium reginae Watt.	x			x							
Cystopteris montana (Lam.) Bernh.		x		x							
Dennstaedia punctilobula (Michx.) Moore			x	x							
Dentaria laciniata Muhl.	x			x							
Deschampsia atropurpurea (Wahl.) Scheele			x	x							
Desmodium canadense (L.) Dc.		x		x							

↑ Forest ↥ Wet forest ↑↑↑ Thicket ꟷ Clearing → Stream, river

⊂→ Lake

Atlantic provinces - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
	N.B.	N.S.	Nfld.	↑	⍏	↑↑↑	⊥⊥⊥	⟶	⊂⊃→	⩊⩊	⋔
Desmodium glutinosum (Muhl.) Wood.	x	x		x							
Dirca palustris L.	x	x		x							
Draba aurea vahl.			x	x							
Dryopteris goldiana (Hokk.) Gray	x			x							
Elymus hystrix L.		x		x							
Equisetum hyemale L.			x	x							
Equisetum palustre L.	x				x						
Festuca obtusa Biehler		x		x							
Floerkea proserpinacoides Willd.		x		x							
Fragaria virginiana Dcne. var. terrae-novae (Rudb.) Fern. & Wieg.			x	x							
Fraxinus pennsylvanica Marsh. var. austini Fern.		x			x						
Galium kamtsehaticum Steller	x			x		x					
Gaultheria procumbens L.			x	x							
Geranium bicknellii Britt.	x			x							
Geranium robertianum L.	x		x	x							
Geum aleppicum Jacq. var. strictum (Ait.) Fern.			x		x	x					
Gnaphalium obtusifolium L.	x			x							
Goodyera oblongifolia Raf.	x	x		x							
Goodyera pubescens (Willd.) R. Br.	x				x						
Goodyera repens (L.) R. Br.		x			x						
Habennaria flava (L.) R. Br.	x	x		x							x
Habennaria macrophylla Goldie	x			x							
Habennaria viridis var. bracteata		x		x		x					
Hackelia americana (Gray) Fern.	x			x							
Helianthemum bicknellii Fern.	x			x							
Helianthus decapetalus L.	x			x		x					
Helianthus giganteus L.	x			x	x						x
Heliopsis helianthoides (L.) Sweet var. scabra (Duval) Fern.	x					x					
Hepatica americana (Dc.) Ker.	x	x		x							
Hepatica nobilis var. obtusa		x		x							
Hydrocotyle americana L.			x		x						
Hystrix patula Moenh. var. bigeloviana (Fern.) Dean	x			x							

↑ Forest
⍏ Wet forest
↑↑↑ Thicket
⊥⊥⊥ Clearing
⟶ Stream, river
⊂⊃→ Lake
⩊⩊ Marsh
⋔ Peat-bog

Atlantic provinces - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
	N.B.	N.S.	Nfld.	Forest	Wet forest	Thicket	Clearing	Stream, river	Lake	Marsh	Peat-bog
Leersia virginica Willd.	x				x	x					
Lilium canadense L.		x			x	x		x			
Listera auriculata Wieg.			x		x	x					x
Listera australis LindBl.	x				x	x					
Listera borealis Morong.			x	x		x					
Lonicera oblongifolia (Goldie) Hook.	x				x						
Luzula acuminata Raf.			x	x							
Luzula parviflora (Ehrh.) Desy.		x			x	x		x			
Lycopodium selago L.	x			x							
Lysimachia quadrifolia L.	x			x							
Millium effusum L.			x	x		x					
Mitchella repens L.			x	x							
Monotropa uniflora L.			x	x							
Orchis rotundifolia	x			x							
Orobanche uniflora (L.) Aschers	x				x	x					
Oryzopsis canadensis (Poir.) Torr.	x	x		x							
Osmorhiza chilensis H. & A.			x	x							
Osmorhiza depauperata		x		x							
Osmorhiza longistylis (Torr.) Dc.	x			x		x					
Osmorhiza obtusa (C. & R.) Fern.	x	x		x							
Osmunda claytoniana L.			x	x	x						
Oxalis acetosella L. var. rhodantha Fern.			x	x							
Panax trifolium L.	x			x							
Panicum depauperatum Muhl.	x			x							
Panicum meridionale Ashe		x		x							
Panicum xanthophysum Gray	x			x							
Pedicularis canadensis L.	x			x							
Petasites vitifolius Greene			x		x						
Phryma leptostachya L.	x			x		x					
Pinus contorta Loud. var. latifolia Engelm.			x								
Pinus resinosa Ait.			x	x							
Platanthera flava (L.) Lindl. var. flava		x			x						x
Platanthera hookeri (Torr.) Lindl.			x	x							
Poa alsodes Gray		x		x							
Polemonium van-bruntiae Britt.	x			x							x

↑ Forest ⊥ Wet forest ↑↑↑ Thicket ⩊ Clearing → Stream, river

⊃ Lake ⩊ Marsh ⩊ Peat-bog

Atlantic provinces - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
	N.B.	N.S.	Nfld.	↑	↥	↑↑↑	⊥⊥⊥	↝	⊸	⩊⩊⩊	⩚
Polygala paucifolia Willd.	x			x							
Polygonum cilinode Michx.			x		x						
Polystichum lonchitis (L.) Roth.		x		x							
Prenanthes trifoliata (Cass.) Fern. var nana (Bigel.) Fern.			x			x					
Pterospora andromeda Nutt.	x			x							
Pyrola asarifolia Michx.		x		x							
Pyrola minor L.	x	x		x		x					
Ranunculus lapponicus L.	x				x						
Ranunculus recurvatus Poir.			x	x							
Rubus occidentalis L.	x			x		x					
Rubus pensilvanicus Poir.			x	x		x					
Salix sericea Marsh.		x			x			x			
Sanicula gregaria Bickn.	x			x							
Sanicula trifoliata Bickn.	x			x							
Scrophularia lanceolata Pursh.	x	x		x		x					
Senecio aureus L.			x		x	x					
Silene antirhinna L.	x			x							
Smilacina racemosa (L.) Desf.			x	x		x					
Solidago caesia L.	x			x							
Stellaria longipes Goldie	x			x							
Streptopus roseus Michx. var. perspectus Fassett			x		x	x					
Symplocarpus foetidus (L.) Nutt.	x	x		x	x						
Teucrium canadense L.	x			x		x					
Thelypteris simulata (Davenp.) Nieuwl.	x			x							x
Thuja occidentalis L.		x		x							
Tiarella cordifolia L.		x		x							
Trillium erectum L.		x		x							
Triostetum aurantiacum Bickn.	x			x		x					
Vaccinium caespitosum Michx.	x			x							
Vaccinium ovalifolium Sm.		x	x	x		x		x			x
Valeriana sitchensis Bong.	x			x							
Verbena urticifolia L.	x			x		x					
Veronica tenella		x									

↑ Forest　↥ Wet forest　↑↑↑ Thicket　⊥⊥⊥ Clearing　↝ Stream, river

⊸ Lake　⩊⩊⩊ Marsh　⩚ Peat-bog

Atlantic provinces - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
	N.B.	N.S.	Nfld.	Forest	Wet forest	Thicket	Clearing	Stream, river	Lake	Marsh	Peat-bog
Viburnum acerifolium	x			x							
Viburnum edule (Michx.) Raf.		x		x		x					
Viburnum lentago L.	x			x							
Viburnum recognitum Fern.	x	x		x							
Viola canadensis L.	x	x		x							
Viola nephrophylla Greene		x			x			x			
Viola renifolia Gray			x	x							
Waldsteinia fragarioides (Michx.) Tratt.	x			x		x					
Woodwardia areolata (L.) Moore		x			x						x
Woodwardia virginica (L.) Sm.	x			x							

Source: NEW-BRUNSWICK: Hind, H., 1981

NOVA-SCOTIA: Maher, R.V. et al., 1978. The Rare Vascular Plants of Nova-Scotia. Botany Division, National Museum of Natural Sciences, Ottawa.

NEWFOUNDLAND: Argus, G.W. and P.J. Scott, 1976. A Preliminary List of of the Rare Plants of Newfoundland and Labrador. Museum of Natural Sciences, Botany Division, Ottawa.

↟ Forest
Wet forest
↟↟↟ Thicket
Clearing
Stream, river
Lake
Marsh
Peat-bog

Province of Quebec - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
				↑	↑≈	↑↑↑	ıııııı	⤳	⊂→	ııııııı	ɷ
Acer nigrum				x							
Adlumia fungosa						x					
Agalinis tenuifolia var. parviflora											
Agalinis tenuifolia var. tenuifolia											
Agastache nepetoides				x		x					
Allium canadense					x						
Amelanchier amabilis						x					
Antennaria parlinii var. parlinii							x				
Aplectrum hyemale				x							
Arabis canadensis				x							
Arabis laevigata				x							
Arethusa bulbosa											x
Arnica chamissonis											x
Asclepias exaltata				x			x				
Asplenium platyneuron var. platyneuron						x					
Aster modestus											x
Astragalus americanus				x							
Athyrium pycnocarpon				x							
Bartonia virginica											x
Bidens discoidea								x			
Camptosorus rhizophyllus				x							
Cardamine bulbosa					x						
Carex adelostoma											
Carex amphibola var. turgida				x							
Carex atrata					x						
Carex baileyi					x						
Carex cristatella											x
Carex cumulata											x
Carex folliculata					x					x	
Carex formosa				x		x					
Carex grayii								x			
Carex hirsutella							x				
Carex laxiculmis				x							
Carex lupuliformis					x			x			

↑ Forest ↑≈ Wet forest ↑↑↑ Thicket ıııııı Clearing ⤳ Stream, river

⊂→ Lake

Province of Quebec - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
				↑	≈↑≈	↑↑↑	ıııı	⤚	⊂⊃→	≈ıııı	ıı͟ı
Carex platyphylla				x							
Carex prasina				x							
Carex richardsonii							x				
Carex sparganioides var. sparganioides					x						
Carex swanii				x			x				
Carex virescens				x			x				
Celtis occidentalis				x							
Cinna arundinacea					x						
Claytonia virginica					x						
Conopholis americana				x							
Cornus racemosa						x					
Corydalis aurea							x				
Crataegus pruinosa var. pruinosa											
Cynoglossum boreale				x							
Cyperus houghtonii				x							
Cypripedium arietinum				x							
Cypripedium reginae					x						x
Decodon verticillatus								x	x		
Dentaria laciniata				x							
Dentaria maxima				x							
Desmodium nudiflorum				x							
Desmodium paniculatum				x			x				
Drosera linearis											x
Dryopteris cristata var. clintoniana				x	x						x
Dryopteris filix-mas				x							
Dryopteris goldiana				x							
Echinochloa walteri										x	x
Elymus riparius								x			
Elymus villosus				x							
Festuca obtusa				x							
Floerkea proserpinacoides					x						
Galium circaezans											
Gentianella crinita ssp. crinita					x						x
Geranium maculatum				x							
Glum laciniatum				x			x				

↑ Forest ≈↑≈ Wet forest ↑↑↑ Thicket ıııı Clearing ⤚ Stream, river

⤚ Lake

Province of Quebec - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
				↑	↑~	↑↑↑	ıııııı	—◆—	⊂⊃	ıııııı	ıılı
Habenaria blepharidiglottis											x
Habenaria flava					x						
Habenaria unalaschcensis var. unalaschcensis				x							
Hackelia virginiana				x							
Hamamelis virginiana				x			x				
Hedeoma pulegioides				x							
Helianthemum canadense				x			x				
Helianthus divaricatus				x			x				
Hieracium paniculatum				x							
Hydrophyllum canadense				x							
Iris versicolor var. shrevei					x					x	
Lactuca hirsuta var. sanguinea				x			x				
Lathyrus ochroleucus				x				x			
Linaria canadensis											x
Listera australis											x
Littorella uniflora var. americana								x	x		
Lysimachia quadrifolia										x	
Muhlenbergia sylvatica				x				x			
Muhlenbergia tenuiflora				x							
Ophioglossum vulgatum var. pseudopodum											x
Orchis spectabilis				x							
Panax quinquefolius				x							
Panicum latifolium				x							
Parietaria pensylvanica				x							
Pedicularis canadensis				x							
Peltandra virginica										x	x
Phytolacca americana				x		x					
Pinus rigida				x							
Poa nemoralis var. interior				x							
Podophyllum peltatum				x							
Polemonium van-bruntiae											x
Polygala paucifolia				x	x						
Polygala polygama var. obtusata				x							
Polygonum hydropiperoides var. hydropiperoides								x			
Potamogeton illinoensis								x	x		

↑ Forest ↑~ Wet forest ↑↑↑ Thicket ıııııı Clearing —◆— Stream, river

⤳ Lake

Province of Quebec - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
				↟	↟~	↟↟↟	ıııı	⤞	↝	ıııııı	ılı
Proserpinaca palustris								x		x	
Pterospora andromeda				x							
Pyrus arbutifolia var. atropurpurea											x
Quercus alba				x							
Quercus bicolor				x							
Ranunculus flabellaris										x	
Ranunculus gmelinii								x		x	
Ranunculus longirostris								x	x		
Rhus radicans var. negundo											
Rhus vernix					x						x
Rhynchospora capillacea											x
Rhynchospora capitellata								x			x
Ribes hudsonianum					x			x			
Salix monticola				x							
Salix serissima											x
Saururus cernuus					x			x			
Scirpus heterochaetus								x	x		
Scirpus torreyi										x	x
Scrophularia marilandica				x							
Selaginella apoda					x						
Sparganium androcladum								x			
Sparganium multipedunculatum									x	x	
Spiranthes casei											
Spiranthes lucida								x		x	
Staphylea trifolia				x		x	x				
Stellaria calycantha var. sitchana											
Taenidia integerrima				x		x					
Thelypteris hexagonoptera				x							
Thelypteris simulata					x						
Triosteum perfoliatum var. aurantiacum				x			x				
Ulmus thomasii				x							
Utricularia geminiscapa										x	
Utricularia gibba									x	x	
Utricularia resupinata									x		
Vaccinium ovalifolium				x							

↟ Forest ↟~ Wet forest ↟↟↟ Thicket ıııı Clearing ⤞ Stream, river

↝ Lake

Province of Quebec - List of rare vascular plants.

SPECIES	PROVINCES			HARITAT							
				↑	⍊	↑↑↑	ıııııı	↝	⊸	ıııııı	ılı
Valeriana sitchensis var. uliginosa					x						x
Veronica comosa var. glandulosa								x		x	
Viburnum rafinesquianum				x							
Vicia americana						x	x				
Viola affinis				x							x
Viola pubescens var. pubescens				x							
Viola rostrata				x							
Viola rotundifolia				x				x			
Viola sagittata var. ovata				x			x				
Viola sagittata var. sagittata				x			x				
Waldsteinia fragarioides				x		x					
Woodwardia virginica					x		x				x

Source: Bouchard *et al.*, 1981.

↑ Forest ⍊ Wet forest ↑↑↑ Thicket ıııııı Clearing ↝ Stream, river

⊸ Lake

Province of Ontario - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
				Forest	Wet forest	Thicket	Clearing	Stream, river	Lake	Marsh	Peat-bog
Adoxa moschatellina L.				x							
Agalinis flava				x							
Agalinis gattingeri Small				x							
Agalinis tenuifolia (Vahl.) Raf. var. parviflora (Nutt.) Pennell				x							
Agastache nepetoides (L.) Ktze,				x		x					
Agastache scrophulariaefolia (Willd.) Ktze.				x		x					
Agrimonia pubescens Wallr.				x							
Altium cernuum Roth.				x							
Alopecurus alpinus Sm.				x							
Amelanchier sanguinea (Pursh.) Dc. var. grandiflora (Wieg.) Rehder				x							
Andropogon virginicus L.				x							
Anemonella thalictroides (L.) Spach.				x							
Aplectrum hyemale (Muhl.) Nutt.				x							
Arabis canadensis L.				x		x					
Arabis perstellata E.L. Braun. var. shortii Fern.				x							
Arenaria macrophylla Hook.				x							
Arisaema dracontium (L.) Schott.				x		x					
Arnica whitneyi Fern.				x							
Artemisia tilesii Ledeb. ssp. elatior (T. & G.) Hult.				x							
Asclepias exaltata L.				x							
Asclepias ovalifolia Dcne.				x							
Asclepias purpurascens L.					x	x					
Asclepias quadrifolia Jacq.				x							
Asclepias verticillata L.				x							
Asclepias viridiflora Raf.				x							
Asimina triloba (L.) Dunal.				x							
Asplenium platyneuron (L.) Oakes				x							
Aster acuminatus Michx.					x						
Aster divaricatus L.				x							
Aster lowrieanus Porter				x		x					
Aster prenanthoides Muhl.				x	x						
Aster sericeus Vent.				x							

↑ Forest
Wet forest
↑↑↑ Thicket
Clearing
Stream, river
Lake
Marsh
Peat-bog

Province of Ontario - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
				Forest	Wet forest	Thicket	Clearing	Stream, river	Lake	Marsh	Peat-bog
Aster shortii Lindl.				x		x					
Astragalus americanus (Hook.) M.E. Jones											
Athyrium pycnocarpon (Spreng.) Tid.				x							
Aureolaria flava (L.) Farw.				x							
Aureolaria pedicularia (L.) Raf.				x							
Aureolaria virginica (L.) Pennell				x							
Baptisia tinctoria (L.) R. Br.				x							
Betula lenta L.				x							
Blephilia ciliata (L.) Benth.				x							
Bromus pubescens Muhl.				x		x					
Buchnera americana L.				x							
Camassia scilloides (Raf.) Cory				x							
Campsis radicans (L.) Seem.				x		x					
Cardamine douglasii Britt.				x							
Carex careyana Torr.				x							
Carex davisii Schwein. & Torr.				x							
Carex folliculata L.				x	x						x
Carex formosa Dewey				x		x					
Carex frankii Kunth				x							
Carex grisea Wahl.				x							
Carex hirsutella Mack.				x			x				
Carex jamesii Schwein.				x							
Carex laevivaginata (KuKenth.) Mack.					x						x
Carex laxiculmis Schwein.				x			x				
Carex laxiflora Lam. var. gracillima (Boott.) Robins & Fern.				x							
Carex leavenworthii Dewey				x							
Carex muskingumensis Schwein.				x							x
Carex novae-angliae Schwein.				x							
Carex oligocarpa Schkuhr.				x		x					
Carex prasina Wahl.				x			x				
Carex richardsonii R. Br.				x							
Carex schweinitzii Dewey				x			x				
Carex shortiana Dewey				x							

Forest — Wet forest — Thicket — Clearing — Stream, river

Lake — Marsh — Peat-bog

Province of Ontario - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
				↑	⊥	↑↑↑	ɯɯɯ	→	⊸	ɯɯɯɯ	ʌʌ
Carex squarrosa L.				x							
Carex swanii (Fern.) Mack.				x		x					
Carex tetanica Schkuhr. var. woodii (Dewey) Wood				x							x
Carex virescens Muhl.				x		x					
Carex willdenowii Schkuhr.				x							
Carya glabra (Mill.) Sweet				x							
Carya laciniosa (Michx.) Loud.				x							
Castanea dentata (Marsh.) Borkh.											
Celtis tenuifolia Nutt.											
Cercis canadensis L.				x							
Chaerophyllum procumbens (L.) Crantz.				x							
Chamaelirium luteum (L.) Gray				x		x					
Chimaphila maculata (L.) Pursh.				x							
Cimicifuga racemosa (L.) Nutt.				x							
Cinna arundinacea L.					x						x
Collinsia verna Nutt.				x		x					
Collinsia canadensis L.					x						
Conopholis americana (L.) Wallr.				x							
Corallorhiza odontorhiza (Willd.) Nutt.				x							
Coreopsis tripteris L.				x		x					
Cornus drummondii E. Mey.					x	x					
Cornus florida L.				x							
Coryadlis flavula (Raf.) Dc.				x							
Crataegus douglasii Lindl.				x							
Cypripedium arietinum R. Br.					x						x
Cypripedium passerinum Richards				x							
Cystopteris montana (Lam.) Bernh.				x		x					
Danthonia compressa				x							
Danthonia sericea Nutt.				x							
Desmodium canescens (L.) Dc.				x							
Desmodium ciliare (Muhl.) Dc.				x							
Desmodium cuspidatum (Muhl.) Loud.				x							
Desmodium marilandicum (L.) Dc.				x							
Desmodium rotundifolium (Michx.) Dc.				x							
Dioscorea villosa L.					x	x					x

↑ Forest
⊥ Wet forest
↑↑↑ Thicket
ɯɯɯ Clearing
→ Stream, river
⊸ Lake
ɯɯɯɯ Marsh
ʌʌ Peat-bog

Province of Ontario - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
				↑ Forest	Wet forest	↑↑↑ Thicket	Clearing	Stream, river	Lake	Marsh	Peat-bog
Disporum lanuginosum (Michx.) Nicholson				x							
Disporum trachycarpum (Wats.) B. & H.				x							
Dryopteris filix-mas (L.) Schott.				x							
Dryopteris goldiana (Hook.) Gray				x							
Dryopteris hexagonoptera				x							
Echinopanax horridum				x							
Elymus diversiglumis Scribn. & Ball.				x		x					
Elymus villosus Muhl.				x		x					
Epilobium panicultaum Nutt. var. subulatum (Haussk.) Fern.				x							
Erigenia bulbosa (Michx.) Nutt.				x							
Erythronium albidum Nutt.				x		x					
Eyonymus atropurpureus Jacq.				x		x					
Eupatorium altissimum L.				x							
Eupatorium coelestinum L.				x	x						
Eupatorium purpureum L.				x							
Euphorbia corollata L.				x							
Euphorbia obtusata Pursh.				x							
Festuca occidentalis Hook.				x		x					
Floerkea proserpinacoides Willd.				x							
Frasera caroliniensis				x							
Fraxinus quadrangulata Michx.					x						
Galium kamtschaticum Steller				x		x					
Galium pilosum Ait.				x							
Gentiana alba Muhl.					x						
Gentiana quinquefolia L.				x							
Gerardia gattingeri				x							
Gerardia tenuifolia var. parviflora				x		x					
Geum vernum (Raf.) T. & G.				x							
Gillenia trifoliata (L.) Moench.				x							
Gleditsia triacanthos L.				x							
Glyceria melicaria (Michx.) Hubbard.					x						
Goodyera oblongifolia Raf.				x							
Gymnocladus dioica (L.) Koch.				x							
Habenaria ciliaris				x		x					

↑ Forest Wet forest ↑↑↑ Thicket Clearing Stream, river

Lake Marsh Peat-bog

Province of Ontario - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
				↑	⊥	↑↑↑	┴┴┴	↝	⬭	ᴗᴗᴗ	⩛
Habenaria flava var. herbiola				x							x
Habenaria unalascensis				x							
Helianthemum bicknellii Fern.				x							
Heuchera americana L.				x							
Hieracium gronovii L.				x		x					
Hieracium paniculatum L.				x							
Hieracium venosum L. car. nudicaule (Michx.) Farw.				x							
Hybanthus concolor (T.F. Forster) Spreng.				x							
Hydrastis canadensis L.				x							
Hydrophyllum appendiculatum Michx.				x							
Hydrophyllum canadense L.					x						
Hypoxis hirsuta (L.) Cox.				x							
Iris brevicaulis Raf.				x							
Iris lacustris Nutt.				x							
Isopyrum biternatum (Raf.) T. & G.				x		x					
Isotrai verticillata (Willd.) Raf.				x							
Jeffersonia diphylla (L.) Pers.				x							
Juglans nigra L.				x							
Koeleria cristata				x							
Koeleria gracilis				x							
Koeleria macrantha				x							
Krigia biflora (Walter) Blake				x							
Lactuca floridana (L.) Gaertn.				x		x					
Lechea leagettii Britt. & Hollick var. moniliformis (Bickn.) Hodgdon				x							
Lechea minor L.				x							
Lechea structa Leggett				x							
Lespedeza intermedia (L.) Pers.				x		x					
Lespedeza violacea (L.) Pers.				x		x					
Lespedeza virginica (L.) Britt.				x		x					
Linum striatum Walt.				x							x
Linum virginianum L.				x		x					
Liparis lilifolia (L.) L.C. Rich				x							
Listera australis Lindl.					x	x					x

↑ Forest ⊥ Wet forest ↑↑↑ Thicket ┴┴┴ Clearing ↝ Stream, river

⬭ Lake ᴗᴗᴗ Marsh ⩛ Peat-bog

Province of Ontario - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
				↑	⍏	↑↑↑	ıııııı	⟶	⊸	⩊⩊⩊	ѱ
Lithospermum latifolium Michx.				x		x					
Lupinus perennis L.				x							
Magnolia acuminata L.				x							
Melica smithii (Porter) Vasey				x							
Mertensia virginica (L.) Pers.				x							
Monarda didyma L.				x		x					
Morus rubra L.				x							
Muhlenbergia schreberi J.F. Gmelin				x		x					
Muhlenbergia sylvatica Torr.				x	x						
Muhlenbergia tenuiflora (Willd.) BSP				x							
Myosotis macrosperma Engelm.				x							
Myosotis verna Nutt.				x							
Nyssa sylvatica Marsh.				x							
Oenothera pilosella Raf.				x							
Onosmodium molle Michx. var. occidentale (Mack.) Johnston					x			x			
Oplopanax horridus (Sm.) Miq.				x							
Orobanche fasciculata Nutt.				x							
Osmorhiza chilensis H.S.A.				x							
Osmorhiza obtusa (Coult. & Rose) Fern.				x							
Oxypolis rigidior (L.) Coult. & Rose					x						x
Panax quinquefolius L.				x							
Panicum calliphyllum Ashe				x							
Panicum clandestinum L.				x		x					
Panicum columbianum Seribn. var. commonsianum (Pshe.) Dore				x							
Panicum depauperatum Muhl.				x							
Panicum depauperatum var. perlongum				x							
Panicum dichotomum L.				x		x					
Panicum lanuginosum Elliott var. praecocius (Hitche & Chase) Dore				x		x					
Panicum latifolium var. clandestinum				x		x					
Panicum leibergii (Vasey) Scribn. var. baldwinii Lepage				x							
Panicum leibergii (Vasey) Scribn. var. leibergii				x							

↑ Forest ⍏ Wet forest ↑↑↑ Thicket ıııııı Clearing ⟶ Stream, river

⊸ Lake ⩊⩊⩊ Marsh ѱ Peat-bog

Province of Ontario - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
				Forest	Wet forest	Thicket	Clearing	Stream, river	Lake	Marsh	Peat-bog
Panicum oligosanthes Schult.				x							
Panicum perlongum Nash.				x							
Panicum philadelphicum Bernh.				x							
Panicum praecocius				x		x					
Panicum sphaerocarpon Ell.				x							
Paronychia canadensis (L.) Wood				x							
Paspalum ciliatifolium Michx.				x							
Penstemon gracilis Nutt.				x							
Phegopteris nexagonoptera (Michx.) Fée				x							
Phlox pilosa L.				x							
Pinus rigida Mill.											
Piperia unalascensis (Spreng.) Rydb.				x							
Plantago cordata Lam.				x							x
Plantanthera ciliaris (L.) Lindl.				x		x					
Plantanthera flava (L.) Lindl. var. herbiola (R. Br.) Wer.				x							
Plantanthera leucophaea (Nutt.) Lindl.											
Poa interior Rydb.				x		x					
Polygonatum biflorum (Wat.) Ell.				x		x					
Polymnia canadensis L.				x							
Polystichum braunii (Spenner) Fée var. purshii Fern.				x							
Prunus americana Marsh.				x		x					
Pterospora andromeda Nutt.				x							
Pycnanthemum incanum (L.) Michx.				x		x					
Pycnanthemum pilosum Nutt.				x		x					
Quercus bicolor Willd.											
Quercus ellipsoidalis E.J. Hill											
Quercus muehlenbergii Engelm.				x							
Quercus palustris Muenchh.				x							x
Quercus prinoides Willd.											
Quercus prinus L.				x							
Ranunculus fascicularis Muhl.				x							
Ranunculus hispidus Michx. var. marilandicus (Por.) Benson				x							

Forest   Wet forest   Thicket   Clearing   Stream, river

Lake   Marsh   Peat-bog

Province of Ontario - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
				Forest	Wet forest	Thicket	Clearing	Stream, river	Lake	Marsh	Peat-bog
Rhus copallina L.				x							
Rosa setigera Michx.				x		x					
Sabatia angularis (L.) Pursh.				x							
Sanicula canadensis L.				x							
Scirpus clintonii Fray				x							
Scirpus verecundus Fern.				x							
Scleria triglomerata Michx.				x							
Scutellaria nervosa Pursh. var. calvifolia Fern.					x	x					
Senecio glabellus Poir.					x						x
Senecio obovatus Muhl.				x							
Silene virginica L.				x							
Silphium perfoliatum L.				x		x					
Sisyrinchium albidum Raf.				x							
Smilax ecirrhata (Engelm.) Wats.				x							
Smilax lasioneuron Hook.				x		x					
Smilax rotundifolia L.				x		x					
Solidago arguta Ait.				x		x					
Solidago jejunifolia Steele				x							
Solidago paluta Muhl.					x						x
Solidago rigida L. var. rigida				x		x					
Solidago speciosa Nutt. var. angustata T. & G.					x	x					
Solidago ulmifolia Nutt.				x		x					
Sphenopholis nitida (Biehler) Scribn.				x							
Sphenopholis obtusata (Michx.) Scribn.				x							
Stylophorum diphyllum (Michx.) Nutt.				x							
Swertia caroliniensis (Walt.) Ktze.				x							
Tephrosia virginiana (L.) Pers.				x							
Thalictrum revolutum Dc.				x		x					
Thalictrum thalictroides				x							
Thaspium barbinode (Michx.) Nutt.				x		x					
Thelypteris hexagonoptera				x							
Tilia heterophylla Vent.				x							
Tradescantia ohioensis Raf.				x		x					
Triosteum angustifolium L.				x		x					
Triophora trianthophora (Sw.) Rydb.				x							

Forest — Wet forest — Thicket — Clearing — Stream, river

Lake — Marsh — Peat-bog

Province of Ontario - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
				↑	⊥	↑↑↑	⩊	⟶	⊃⟶	⩊⩊	⩙
Vaccinium ovalifolium Sm.				x		x					
Vaccinium pallidum Ait.				x							
Vaccinium stamineum L.				x		x					
Vaccinium vacillans				x							
Valeriana uliginosa T. & G.					x						x
Veronicastrum virginicum (L.) Farw.				x		x					
Viburnum dentatum L. var. lucidum Ait.				x		x					
Vicia caroliniana Walt.				x		x					
Viola palmata L.				x							
Viola rotundifolia Michx.				x							
Viola sagittata Ait.				x							
Viola striata Ait.				x							
Viola triloba Schwein.				x							
Vitis aestivalis Michx.				x		x					
Woodsia obtusa (Spreng.) Torr.				x							
Uvularia perfoliata L.				x		x					

Source: Argus and White, 1977.

↑ Forest ⊥ Wet forest ↑↑↑ Thicket ⩊ Clearing ⟶ Stream, river

⊃⟶ Lake ⩊⩊ Marsh ⩙ Peat-bog

Prairie provinces - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
	Alta.	Sask.	Man.	↑	⊥	↑↑↑	⌴	⤳	⊸	⏝	⩚
Adenocaulon bicolor Hook.	x				x	x					
Adlumia fungosa (Ait.) Greene			x		x						
Adoxa noschatellina L.		x	x		x						
Allium cernuum Roth.		x		x							
Allium tricoccum Ait.			x	x							
Alopecurus alpinus Sm. ssp. glaucus (Less.) Hult.		x		x							
Anaphalis margaritacea (L.) Benth. & Hook. f.		x		x							
Anemone nemorosa L. var. bifolia (Farwell) Boivin	x	x		x	x						
Anemone parviflora Michx.		x			x						
Anemone quinquefolia var. interior	x	x		x	x						
Angelica dawsonii Wats.	x			x				x			
Antennaria corymbosa E. Nels.	x	x		x	x						
Antennaria neglecta Green var. attenuata (Fern.) Crong.		x		x							
Antennaria neodioica		x		x							
Antennaria russellii Boivin		x		x							
Arabis lyrata L.			x	x							
Aralia racemosa L.			x		x						
Arceuthobium pusillum Peck.		x		x							
Arethusa bulbosa L.		x	x		x						x
Arisaema triphyllum L.			x	x							
Arnica cordifolia Hook.			x	x							
Arnica parryi Gray	x			x							
Aster eatonii (Gray) Howell		x			x	x					
Aster macrophyllus L.			x	x							
Athyrium filix-femina (L.) Roth. var. michauxii (Spreng.) Farw.		x		x	x						
Balsamorhiza sagittata (Pursh.) Nutt.	x			x							
Botrychium lanceolatum (Gmelin) Rupr. var. lanceolatum	x			x							
Botrychium lunaria (L.) Sw.		x		x							
Botrychium multifidum (Gmelin) Rupr.		x		x				x	x		
Bromus purgans L.	x			x		x					

↑ Forest
⊥ Wet forest
↑↑↑ Thicket
⌴ Clearing
⤳ Stream, river
⊸ Lake
⏝ Marsh
⩚ Peat-bog

Prairie provinces - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
	Alta.	Sask.	Man.	↟	↟≈	↟↟↟	ɯɯɯ	⤳	⊂⊃→	⩊⩊⩊	ѱ
Calamagrostis rubescens Buckl.		x		x							
Calypso bulbosa (L.) Oakes		x		x							
Cardamine parviflora L. var. arenicola (Britt.) O.E. Schulz	x	x		x							
Carex arcta Boott.		x	x	x							
Carex arctata Boott.			x	x		x					
Carex assiniboinensis W. Boott.		x		x							
Carex blanda			x	x		x					
Carex crinita Lam. var. crinita			x	x							
Carex gravida Bailey		x		x							
Carex laxiflora Lam. var. blanda (Dew.) Boott.		x	x	x		x					
Carex loliacea L.			x		x						
Carex pedunculata Muhl.		x		x							
Carex raynoldsii Dew.		x		x							
Carex tetanica var. Woodii Dew.			x	x							
Caulophyllum thalictroides (L.) Michx.			x	x							
Celastrus scandens L.		x									
Cerastium alpinum L.		x									
Chimaphila umbellata (L.) Bart. ssp. occidentalis (Rydb.) Hult.		x		x							
Circaea lutetiana L. ssp. canadensis (L.) Aschers & Magnes			x	x							
Circaea quadrisulcata var. canadensis			x	x							
Cirsium hookerianum var. scariosum (Nutt.) Boivin	x			x			x				
Claytonia lanceolata Pursh.		x		x							
Clematis virginiana L.			x			x					
Clematis occidentalis Hornem. var. grosseserrata (Rydb.) Pringle		x		x							
Clematis verticillaris var. columbiana		x		x							
Gollinsia parviflora Lindl.		x		x							
Conopholis americana (L.) Wallr.			x	x							
Corallorhiza striata Lindl.		x		x							
Cornus rugosa Lam.			x	x							
Cryptantha affinis (Gray) Greene	x			x							

↟ Forest ↟≈ Wet forest ↟↟↟ Thicket ɯɯɯ Clearing ⤳ Stream, river

⊂⊃→ Lake ⩊⩊⩊ Marsh ѱ Peat-bog

Prairie provinces - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
	Alta.	Sask.	Man.	↑	⊥	↑↑↑	⫫⫫	⤳	⊂⊃	⫫⫫⫫	⩚
Cryptotaenia canadensis (L.) Dc.			x		x						
Cypripedium acaule Ait.	x			x							x
Cypripedium arietinum R. Br.		x	x	x	x						
Cypripedium montanum Dougl.	x				x						
Cypripedium reginae Walt.		x			x						
Cystopteris montana (Lam.) Bernh.		x			x						
Delphinium glaucum S. Wats.		x									
Dicentra cucullaria (L.) Bernh.			x	x							
Diervilla lonicera Mill.		x		x							
Disporum hookeri var. oreganum	x				x						
Dryopteris cristata (L.) Gray	x				x						
Dryopteris filix-mas (L.) Schott.	x			x							
Dryopteris phegopteris	x		x		x						
Elymus glaucus Buckl.		x		x							
Elymus hystrix L.			x		x						
Elymus virginicus L.	x			x		x					
Epilobium platyphyllum	x										
Erigeron hyssopifolius Michx.		x			x						x
Festuca brachyphylla Schult.		x		x							
Festuca idahoensis Elmer		x		x							
Festuca obtusa Biehler			x		x						
Festuca occidentalis Hook. var. occidentalis	x			x		x					
Festuca subulata Trin.	x				x						
Galium aparine L.			x		x						
Gaultheria humifusa (Graham) Rydb.	x				x	x					
Geranium richardsonii Fisch. & Trautv.		x		x							
Glyceria elata (Nash.) M.E. Jones	x				x						
Gnaphalium viscosum HBK.	x			x			x				
Goodyera oblongifolia Raf.		x		x							
Goodyera tesselata Lodd.			x	x							
Habenaria hookeri			x	x							
Habenaria lacera			x	x		x					
Habenaria orbiculata		x		x							
Habenaria saccata	x			x							

↑ Forest ⊥ Wet forest ↑↑↑ Thicket ⫫⫫ Clearing ⤳ Stream, river

⊂⊃ Lake ⫫⫫⫫ Marsh ⩚ Peat-bog

Prairie provinces - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
	Alta.	Sask.	Man.	↑	⍊	↑↑↑	⩊	↝	⊂⊃	⩋	⩓
Helopsis helianthoides (L.) Sweet var. scabra (Dunal) Fern.		x									
Hepatica americana (Dc.) Ker.			x	x							
Heracium albiflorum Hook.		x		x							
Hypopitys monotropa	x	x	x	x							
Hypoxis hirsuta (L.) Coville		x									
Hystrix patula			x	x							
Impatiens noli-tangere L.			x		x						
Krigia biflora (Walt.) Blake			x	x							
Lactuca floridana (L.) Gaertn.			x			x					
Laportea canadensis (L.) Wedd.		x		x							
Larix occidentalis Nutt.	x			x							
Lechea intermedia Leggett. var. clepauperata Hodadon		x		x							
Listera borealis Morong.		x		x							
Listera caurina Piper	x				x			x			
Listera cordata (L.) R. Br.		x		x							
Listera convallarioides (Swartz) Nutt.	x				x						x
Loiseleuria procumbens (L.) Desv.		x									
Lonicera hirsuta Eaton var. schindleri Boivin			x	x							
Luzula acuminata Raf.	x			x							
Lycopodium lucidulum Michx.			x			x					
Lycopodium selago L.		x		x							
Lycopodium sabinaefolium ssp. sitchense Rupr.		x		x							
Lycopodium tristachyum Pursh.			x	x			x				
Malaxis monophyllos (L.) Sw. var. brachypoda (Gray) Morris & Eames	x	x	x		x						
Malaxis unifolia Michx.			x	x						x	
Melica smithii (Porter) Vasey	x				x						
Melica spectabilis Scribn.	x			x							
Microseris nutans (Geyer) Schultz-Bip		x		x							
Milium effusum L. var. cisatlanticum Fern.		x		x			x				
Mimulus guttatus Dc.	x	x		x				x			
Monotropa hypopitys L.	x	x	x	x							
Orobanche uniflora L.	x	x		x	x						

↑ Forest ⍊ Wet forest ↑↑↑ Thicket ⩊ Clearing ↝ Stream, river

⊂⊃ Lake ⩋ Marsh ⩓ Peat-bog

Prairie provinces - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
	Alta.	Sask.	Man.	↑	⊥	↑↑↑	⩊	→	⊂⊃	≈	⋀
Oryzopsis canadensis (Poir.) Torr.	x		x	x		x					
Oryzopsis exigua Thurb.	x			x							
Oryzopsis micrantha (Trin. & Rupr.) Thurb.	x		x	x							
Osmorhiza aristata var. longistylis	x			x							
Osmorhiza chilensis var. purpurea	x			x							
Osmorhiza claytoni (Michx.) Clarke			x	x							
Osmorhiza longistylis (Torr.) Dc.	x				x						
Osmorhiza occidentalis (Nutt.) Torr.	x			x							
Ostrya virginiana (Mill.) Koch.			x	x							
Pachistima myrsinites (Pursh.) Raf.	x			x							
Panicum linearifolium Scribn.			x	x							
Panicum perlongum Nash.			x	x							
Panicum subvillosum Ashe		x		x							
Pedicularis groenlandica Retz.		x		x							
Pedicularis labradorica Wirsing		x		x							
Pedicularis racemosa Dougl. var. alba (Pennel) Crong.	x			x							
Penstemon fructicosus (Pursh.) Green ssp. scouleri (Lindl.) Penn & Keck	x			x							
Perideridia gairdneri (H. & A.) Mathias ssp. borealis Chuang & Const.		x		x							
Phegopteris connectilis (Michx.) Watt.			x		x						
Phegopteris polypodioides Fée.	x	x			x			x			
Physalis grandiflora Hook.		x		x							
Physocarpus malvaceus (Greene) Kuntze	x			x		x	x				
Pinus monticola Dougl.	x			x							
Pinus resinosa Ait.			x	x							
Pinus strobus L.			x								
Platanthera hookeri (Torr.) Lindl.			x		x						
Platanthera lacera (Michx.) G. Don			x	x		x					
Platanthera saccata	x			x							
Platanthera orbiculata (Pursh.) Lindl.		x		x							
Platanthera stricta Lindl.	x			x							x
Poa arctica R. Br.		x		x							
Polygala paucifolia Willd.	x	x		x							

↑ Forest ⊥ Wet forest ↑↑↑ Thicket ⩊ Clearing → Stream, river

⊂⊃ Lake ≈ Marsh ⋀ Peat-bog

Prairie provinces - List of rare vascular plants.

SPECIES	PROVINCES			HARITAT							
	Alta.	Sask.	Man.	↟	⊥	↟↟↟	ɯɯɯ	⤞	⊂⊃	ɯɯɯɯ	⩚
Polygonatum canaliculatum (Muhl.) Pursh.		x		x				x			
Populus angustifolia James	x	x		x				x			
Populus grandidentata Michx.			x	x							
Potentilla quinquefolia Rydb.		x		x							
Prenanthes alba L.		x		x		x					
Prenanthes sagittata (Gray) A. Nels.	x				x						
Prunus americana Marsh. var. americana		x		x							
Pteridium aquilinum (L.) Kuh. var. pubescens Underw.	x			x		x					
Pterospora andromeda Nutt.	x	x		x							
Pyrola bracteata Hook.	x				x						
Pyrola grandiflora		x		x							
Pyrola picta Sm.	x				x						
Pyrola rotundifolia L. var. americana (Sweet) Fern.			x	x							
Pyrola rotundifolia L. ssp. grandiflora (Rad.) Andres		x		x							
Ranunculus inamoenus Greene		x		x							
Ranunculus fascicularis Muhl.			x	x							
Rhus glabra L.		x		x							
Ribes aureum Pursh.		x		x		x					
Ribes inerme Rydb.	x			x							
Ribes laxiflorum Pursh.	x				x						
Ribes oxyacanthoides var. saxosum	x			x							
Ribes viscosissimum Pursh.	x			x							
Salix arbusculoides Anderss.			x	x							
Salix calcicola Fern. & Wieg.	x			x							
Salix sitchensis Sanson	x										
Salix stolonifera Cov.	x										
Salix vestita Pursh.			x	x							
Sambucus pubens Michx.		x			x						
Sanguinaria canadensis L.			x	x							
Scirpus clintonii Gray	x	x		x							
Senecio hydrophiloides Rydb.	x			x							
Smilacina amplexicaulis Nutt.		x	x	x							

↟ Forest ⊥ Wet forest ↟↟↟ Thicket ɯɯɯ Clearing ⤞ Stream, river

⊂⊃ Lake ɯɯɯɯ Marsh ⩚ Peat-bog

Prairie provinces - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
	Alta.	Sask.	Man.	↑	⍏	↑↑↑	ıııı	⤳	⊸	⏜	⩙
Spiraea betulifolia var. lucida		x		x							
Spiraea densiflora Nutt. var. spendens (Bauman) C.L. Hitchc.	x			x		x					
Stipa richardsonii Link.			x	x							
Streptopus amplexifolius (L.) Dc. var. americanus Schuttes		x			x						
Streptopus streptopoides (Ledeb.) Frye & Rigg.	x			x							
Taxus brevifolia Nutt.	x				x						
Taraxacum ceratophorum (Ledeb.) Dc.		x		x							
Thalictrum occidentale (Gray)		x			x						
Thelypteris phegopteris	x	x		x	x			x			
Thuja picata D. Don.	x			x							
Tiarella trifoliata L.	x				x						
Trillium cernuum L.		x		x							
Trillium ovatum Pursh.	x				x						
Trisetum spicatum (L.) Richt. sens. lat.		x		x							
Trisetum canescens Buckl.	x										
Trisetum cernuum Trin.	x				x						
Trisetum montanum Vasey.	x										
Uvularia sessilifolia L.			x	x		x					
Vaccinium caespitosum Michx.			x	x			x				
Verbena urticifolia L.		x				x					
Viburnum lentago L.		x			x						
Viola pubescens Ait. var. leiocarpa (Fern. & Wieg.) Boivin		x			x						
Viola selkirkii Pursh.	x	x	x		x						

Source: Argus and White, 1978 (Alberta)
Maher *et al.*, 1979 (Saskatchewan)
White and Johnson, 1980 (Manitoba)

↑ Forest ⍏ Wet forest ↑↑↑ Thicket ıııı Clearing ⤳ Stream, river

⊸ Lake ⏜ Marsh ⩙ Peat-bog

Province of British Columbia - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
				↑	⊥	↑↑↑	ɯɯɯ	→	⊸	ʍʍʍ	⩚
Adiantum pedatum				x							
Asclepias ovalifolia Dene.											
Astragalus williamsii Rydb.				x							
Boschniakia rossica (C. & S.) Fedtsch.											
Calochortus lyallii				x							
Cimicifuga elata Nutt.					x						
Claytonia tuberosa Pallas.				x							
Danthonia sericea Nutt.				x							
Dryopteris arguta				x							
Dryopteris cristata					x	x					
Eburophyten austiniae				x							
Euonymus occidentalis				x							
Galium labradoricum Wieg.				x		x					x
Haploppapus bloomeri Gray				x							
Helopsis helianthoides (L.) Sweet				x							
Hydrophyllum tenuipes					x						
Lewisia triphylla				x							
Lewisia tweedyi				x							
Luina nardosmia Gray				x							
Lupinus kushei Eastw.				x				x			
Montea diffusa					x						
Ophioglossum vulgatum				x		x					
Orobanche pinorum Geyer				x							
Oryzopsis canadensis (Poir.) Torr.				x							x
Oxalis oregana					x						
Penstemon gracilis Nutt.				x							
Phlox speciosa				x							
Pinus banksiana Lamb.											
Plantanthera unalascensis (Spreng.) Kurtz. ssp. maritima (Rydb.) Defilipps				x							
Pleuropogon refractus				x							
Polygala senega L.					x						
Polygonum austiniae				x							
Polygonum majies				x							
Polypodium virginianum L.				x							

↑ Forest ⊥ Wet forest ↑↑↑ Thicket ɯɯɯ Clearing → Stream, river

⊸ Lake ʍʍʍ Marsh ⩚ Peat-bog

Province of British Columbia - List of rare vascular plants.

SPECIES	PROVINCES			HABITAT							
				↑	⊥	↑↑↑	ɯɯɯ	⤳	⊂⊃	ɯɯɯ	ѡ
Polystichum californicum				x				x			
Ranunculus rhomboideus Goldie				x							
Spraguea umbellata				x							
Thelypteris nevadensis				x							
Toxicodendron diversilobum				x		x					
Trillium ovatum					x						

↑ Forest ⊥ Wet forest ↑↑↑ Thicket ɯɯɯ Clearing ⤳ Stream, river

⊂⊃ Lake ɯɯɯ Marsh ѡ Peat-bog

Appendice III

Scientific and common names of mammals, birds, freshwater fishes, and reptiles and amphibians

Mammals*

Scientific name	English	French	Status**	Life form	Province			
					Atl.	Cont.	Prai.	B.C.
ORDER: INSECTIVORA FAMILY: SORICIDAE								
Sorex arcticus	Arctic shrew	Musaraigne arctique	T	3.2	X			
Sorex gaspensis	Gaspé shrew	Musaraigne de Gaspé	T	3.2	X			
ORDER: LAGOMORPHA FAMILY: LEPORIDAE								
Sylvilagus floridanus	Eastern cottontail	Lapin à queue blanche	R,P	2.3		X	X	X
Lepus americanus	Snowshoe hare	Lièvre d'Amérique	R,P	2.5	X	X	X	X
Lepus townsendii	White-tailed jack rabbit	Lièvre de Townsend	R	2.3			X	X
ORDER: RODENTIA FAMILY: AGLODONTIDAE								
Aplodontia rufa	Mountain beaver	Castor de montagne	R,P	3.1				X
FAMILY: SCIURIDAE								
Tamias striatus	Eastern chipmunk	Tamia rayé	P	1,5	X	X	X	
Eutamias amoenus	Yellow pine chipmunk	Tamia amène		2.1				X
Eutamias townsendii	Townsend's chipmunk	Tamia de Townsend	P	2.3				X
Marmota vancouverensis	Vancouver Island marmot	Marmotte de l'Île Vancouver	T	2.3				X
Sciurus carolinensis	Grey squirrel	Ecureuil gris	R,P	1.7	X	X	X	
Sciurus niger	Fox squirrel	Ecureuil fauve	T	1.7		X		
Tamiasciurus hudsonicus	American red squirrel	Ecureuil roux	R,P	1.11	X	X	X	X
Tamiasciurus douglasii	Douglas's squirrel	Ecureuil de Douglas	P	1.3				X
FAMILY: CASTORIDAE								
Castor canadensis	American beaver	Castor	R,P	3.1	X	X	X	X
FAMILY: MURIDAE								
Peromyscus maniculatus	Deer mouse	Souris sylvestre	P	2.5		X	X	X
Peromyscus leucopus	White-footed mouse	Souris à pattes blanches	P	1.5	X	X	X	X
Clethrionomys gapperi	Gapper's red-backed vole	Campagnol à dos roux de Gapper	P	1.1	X	X	X	X
Ondatra zibethicus	Muskrat	Rat musqué	R	3.1	X	X	X	X
Microtus pennsylvanicus	Meadow vole	Campagnol des champs	P	2.3	X	X	X	X
Microtus chrotorrhinus	Rock vole	Campagnol des rochers	T	1.1	X	X	X	X
FAMILY: ERETHIZONTIDAE								
Erethizon dorsatum	American porcupine	Porc-épic d'Amérique	R,P	2.5	X	X	X	X
ORDER: CARNIVORA FAMILY: CANIDAE								
Canis latrans	Coyote	Coyote	R	2.2		X	X	X
Canis lupus	Wolf	Loup	R,T	2.6	X	X	X	X
Vulpes vulpes	Red fox	Renard roux	R	2.2	X	X	X	X
Urocyon cinereoargentus	Grey fox	Renard gris	T	1.6		X	X	
FAMILY: URSIDAE								
Ursus americanus	American black bear	Ours noir	R	2.6	X	X	X	X
Ursus arctos	Grizzly bear	Ours brun	R,T	1.2			X	X
FAMILY: PROCYONIDAE								
Procyon lotor	Raccoon	Raton laveur	R	2.8	X	X	X	X
FAMILY: MUSTELIDAE								
Martes americana	American marten	Martre d'Amérique	R,T	1.4	X	X	X	X
Martes pennanti	Fisher	Pékan	R	1.2		X	X	X
Mustela erminea	Ermine	Hermine	R	2.6	X	X	X	X
Mustela frenata	Long-tailed weasel	Belette à longue queue	R	2.2	X	X	X	X
Mephitis mephitis	Striped skunk	Mouffette rayée	R	2.6	X	X	X	X

Mammals (cont'd)*

Scientific name	English	French	Status**	Life form		Province		
					Atl.	Cont.	Prai.	B.C.
Mustela nivalis	Least weasel	Belette pigmée	R	2.2		X	X	X
Mustela vison	American mink	Vison d'Amérique	R	3.2	X	X	X	X
Gulo gulo	Wolverine	Carcajou	R,T	2.4		X	X	X
Taxidea taxus	American badger	Blaireau d'Amérique	R,T	2.4		X	X	X
Lontra canadensis	River otter	Loutre de rivière	R	3.2	X	X	X	X
FAMILY: FELIDAE								
Felis concolor cougar	Eastern cougar	Couguar de l'est	T	2.6	X	X		
Felis concolor oregonensis et Felis concolor missoulensis	Mountain lion	Couguar	R,T	2.6		X	X	X
Lynx lynx	Lynx	Loup-cervier	R	1.2	X	X	X	X
Lynx rufus	Bobcat	Lynx roux	R	2.6		X	X	X
ORDER: ARTIODACTYLA FAMILY: CERVIDAE								
Rangifer tarandus caribou	Woodland caribou	Caribou des bois	R	1.1	X	X	X	X
Odocoileus hemionus columbianus	Black-tailed deer	Cerf à queue noire	R	2.1				X
Odocoileus hemionus hemionus	Mule deer	Cerf mulet	R,T,P	2.1			X	X
Odocoileus virginianus	White-tailed deer	Cerf de Virginie	R,P	2.1	X	X	X	X
Alces alces	Moose	Orignal	R,P	2.1	X	X	X	X
Cervus elaphus nelsoni et Cervus elaphus manitobensis	American elk	Wapiti	R	2.1		X	X	X
Cervus elaphus roosevelti	Roosevelt elk	Wapiti de Roosevelt	T	2.1				X
Antilocapra americana	Pronghorn	Antilope d'Amérique	R	2.3			X	
FAMILY: BOVIDAE								
Bison bisonathabascae	Wood bison	Bison	T	2.3			X	X
Oreamnos americanus	Mountain goat	Chèvre de montagne	R	2.3				X
Ovis canadensis canadensis	Rocky mountain bighorn	Moufflon d'Amérique	R	2.3			X	X

* The names of mammals adopt the systems used by Banfield (1974).

** Status

R : Recreational and commercial species; T : rare, threatened or endangered species; P : potential pest species

Birds*

Scientific name	English	French	Status**	Life form	Province Atl.	Cent.	Prai.	B.C.
ORDER: GAVIIFORMES FAMILY: GAVIIDAE								
Gavia immer	Common Loon	Huart à collier	T	3.2	X	X	X	X
ORDER: PODICIPEDIFORMES FAMILY: PODICIPEDIDAE								
Aechmophorus occidentalis	Western Grebe	Grèbe de l'ouest	T	3.2			X	X
ORDER: PELECANIFORMES FAMILY: PELECANIDAE								
Pelecanus erythrorhynchos	White Pelican	Pélican blanc	T	3.2			X	X
FAMILY: PHALACROCORACIDAE								
Phalacrocorax auritus	Double-crested Cormorant	Cormoran à aigrettes	T	3.2	X	X	X	
ORDER: ANSERIFORMES FAMILY: ANATIDAE								
Olor buccinator	Trumpeter Swan	Cygne trompette	T	3.1			X	X
Branta canadensis	Canada Goose	Bernache canadienne	R	3.1	X	X	X	X
Branta bernicla	Brent Goose	Bernache cravant	R	3.1			X	
Anser albifrons	White-fronted Goose	Oie à front blanc	R	3.1			X	X
Chen caerulescens	Snow Goose	Oie blanche	R	3.1	X	X	X	X
Anas platyrhynchos	Mallard	Canard malard	R	3.1		X	X	X
Anas rubripes	Black Duck	Canard noir	R	3.1	X	X		
Anas strepera	Gadwall	Canard chipeau	R	3.1			X	X
Anas acuta	Pintail	Canard pilet	R	3.1	X	X	X	X
Anas carolinensis	Green-winged Teal	Sarcelle à ailes vertes	R	3.1	X	X	X	X
Anas discors	Blue-winged Teal	Sarcelle à ailes bleues	R	3.1	X	X	X	X
Anas cyanoptera	Cinnamon Teal	Sarcelle cannelle	R	3.1			X	X
Mareca americana	American Widgeon	Canard siffleur d'Amérique	R	3.1	X	X	X	X
Spatula clypeata	Shoveler	Canard souchet	R	3.1			X	X
Aix sponsa	Wood Duck	Canard huppé	R	3.3		X	X	X
Aythya americana	Redhead	Morillon à tête rouge	R	3.1			X	X
Aythya collaris	Ring-necked Duck	Morillon à collier	R	3.1	X	X	X	X
Aythya valisineria	Canvasback	Morillon à dos blanc	R	3.1			X	X
Aythya marila	Greater Scaup	Grand morillon	R	3.1	X	X	X	X
Aythya affinus	Lesser Scaup	Petit morillon	R	3.1	X	X	X	X
Bucephala clangula	Common Goldeneye	Garrot commun	R	3.3	X	X	X	X
Bucephala islandica	Barrow's Goldeneye	Garrot de Barrow	R	3.3	X	X	X	X
Bucephala albeola	Bufflehead	Petit garrot	R	3.3			X	X
Histrionicus histrionicus	Harlequin Duck	Canard arlequin	R	3.1	X	X		X
Oxyura jamaicensis	Ruddy Duck	Canard roux	R	3.1			X	X
Lophodytes cucullatus	Hooded Merganser	Bec-scie couronné	R	3.4	X	X	X	X
Mergus merganser	Common Merganser	Bec-scie commun	R	3.4	X	X	X	X
Mergus serrator	Red-breasted Merganser	Bec-scie à poitrine rousse	R	3.2	X	X	X	X
ORDER: FALCONIFORMES FAMILY: ACCIPITRADAE								
Buteo lineatus	Red-shouldered Hawk	Buse à épaulettes rousses	T	1.8	X	X		
Buteo swainsoni	Swainson's Hawk	Buse de Swainson	T	2.4			X	X
Buteo regalis	Ferruginous Hawk	Buse rouilleuse	T	2.4			X	X
Aquila chrysaetos	Golden Eagle	Aigle doré	T	2.4	X	X	X	X
Haliaeetus leucocephalus	Bald Eagle	Aigle à tête blanche	T	3.4	X	X	X	X
FAMILY: PANDIONIDAE								
Pandion haliaetus	Osprey	Aigle pêcheur	T	3.4	X	X	X	X
FAMILY: FALCONIDAE								
Falco mexicanus	Prairie Falcon	Faucon des prairies	T	2.4			X	X
Falco peregrinus anatum	Peregrine Falcon (anatum)	Faucon pèlerin (anatum)	T	2.2		X		X

Birds (cont'd)*

Scientific name	English	French	Status**	Life form	Province Atl.	Province Cont.	Province Prai.	Province B.C.
Falco peregrinus pealei	Peregrine Falcon (pealei)	Faucon pèlerin (pealei)	T	2.2	X	X	X	X
Falco columbarius	Pigeon Hawk	Faucon émerillon	T	2.8	X	X	X	X
ORDER: GALLIFORMES FAMILY: TETRAONIDAE								
Dendragapus obscurus	Blue Grouse	Tétras sombre	R,P	1.1				X
Canachites canadensis	Spruce Grouse	Tétras des savanes	R,P	1.1	X	X	X	X
Bonasa umbellus	Ruffed Grouse	Gélinotte huppée	R	2.1	X	X	X	X
Lagopus lagopus	Willow Ptarmigan	Lagopède des saules	R	2.3	X	X	X	X
Lagopus leucurus	White-tailed Ptarmigan	Lagopède à queue blanche	R	2.3				X
Pedioecetes phasianellus	Sharp-tailed Grouse	Gélinotte à queue fine	R	2.3		X	X	X
Centrocercus urophasianus	Sage Grouse	Gélinotte des armoises	R	2.3			X	X
FAMILY: PHASIANIDAE								
Colinus virginianus	Bobwhite	Colin de Virginie	R	2.1		X		X
Lophortyx californicus	California Quail	Colin de Californie	R	2.1				X
Phasianus colchicus	Ring-necked Pheasant	Phaisant à collier	R	2.3	X	X	X	X
Alectoris graeca	Chukar	Perdrix bartavelle	R	2.3				X
Perdrix perdrix	Grey Partridge	Perdrix européenne	R	2.3	X	X	X	X
ORDER: GRUIFORMES FAMILY: GRUIDAE								
Grus americana	Whooping Crane	Grue blanche d'Amérique	T	3.2			X	
Grus canadensis	Sandhill Crane	Grue canadienne	R,T	3.2			X	X
FAMILY: RALLIDAE								
Rallus sp.	Rails	Râles	R	3.2	X	X	X	X
Gallinula chloropus	Common Gallinule	Gallinule commune	R	3.2		X		
Fulica americana	American Coot	Foulque américaine	R	3.2		X	X	X
ORDER: CHARADRIIFORMES FAMILY: CHARADRIIDAE								
Charadrius melodus	Piping Plover	Pluvier siffleur	T	3.1	X	X	X	
FAMILY: SCOLOPACIDAE								
Philohela minor	American Woodcock	Bécasse américaine	R	3.1		X		
Capella gallinago	Common Snipe	Bécassine ordinaire	R	3.1	X	X	X	X
FAMILY: ALCIDAE								
Synthliboramphus antiquus	Ancient Murrelet	Alque à cou blanc	R	3.2				X
ORDER: COLUMBIFORMES FAMILY: COLUMBIDAE								
Columba fasciata	Band-tailed Pigeon	Pigeon du Pacifique						X
Zenaidura macroura	Mourning Dove	Tourtelle triste						X
ORDER: STRIGIFORMES FAMILY: STRIGIDAE								
Speotyto cunicularia	Burrowing Owl	Chouette des terriers	T	2.4				
Strix nebulosa	Great Gray Owl	Chouette cendrée	T	1.4		X	X	X
Asio otus	Long-eared Owl	Hibou à aigrettes longues	T	1.4	X	X	X	X
Asio flammeus	Short-eared Owl	Hibou des marais	T	2.4	X	X	X	X
Aegolius funereus	Boreal Owl	Nyctale boréale	T	1.4		X	X	X
Surnia ulula	Hawk Owl	Chouette épervière	T	1.4	X	X	X	X
ORDER: PICIFORMES FAMILY: PICIDAE								
Sphyrapicus varius	Yellow-bellied Sapsucker	Pic maculé	P	1.8	X	X	X	X
ORDER: PASSERIFORMES FAMILY: PARULIDAE								
Dendroica kirtlandii	Kirland's Warbler	Fauvette de Kirtland	T	2.2		X		

* The names of birds adopt the systems used by Godfrey (1967).

** Status

R : Recreational and commercial species; T : rare, threatened or endangered species; P : potential pest species

Freshwater fishes*

Scientific name	English	French	Status**	Life form	Province			
					Atl.	Cent.	Prai.	B.C.
ORDER: ACIPENSERIFORMES FAMILY: ACIPENSERIDAE								
Acipenser brevirostrum	Shortnose sturgeon	Esturgeon à museau court	T	4.2	X			
Acipenser fulvescens	Lake sturgeon	Esturgeon de lac	R,T	4.2		X	X	
Acipenser oxyrhynchus	Atlantic sturgeon	Esturgeon noir	R	4.3	X	X		
Acipenser transmontanus	White sturgeon (Pacific)	Esturgeon blanc	R	4.2				X
ORDER: CLUPEIFORMES FAMILY: CLUPEIDAE								
Alosa aestivalis	Blueback herring	Alose d'été	R,T	4.2	X			
Alosa pseudoharengus	Alewife	Gaspareau	R	4.2	X	X		
Alosa sapidissima	American shad	Alose savoureuse	R	4.2	X	X		X
FAMILY: SALMONIDAE								
Oncorhynchus gorbuscha	Pink salmon	Saumon rose	R	4.2				X
Oncorhynchus keta	Chum salmon	Saumon kéta	R	4.2				X
Oncorhynchus kisutch	Coho salmon	Saumon Coho	R	4.1				X
Oncorhynchus nerka	Sockeye salmon (Kokanee)	Kokani	R	4.2				X
Oncorhwynchus tshawytscha	Chinook salmon	Saumon chinook	R	4.2				X
Salmo clarki	Cutthroat trout	Truite fardée	R	4.1				X
Salmo gairdneri	Rainbow trout	Truite arc-en-ciel	R	4.1	X	X	X	X
Salmo salar	Atlantic salmon	Saumon atlantique	R	4.1	X	X		
Salmo trutta	Brown trout	Truite brune	R	4.2	X	X	X	
Salvelinus alpinus	Arctic char	Omble chevalier	R	4.1	X	X		
Salvelinus fontinalis	Brook trout	Omble de fontaine	R	4.1	X	X	X	X
Salvelinus timagamiensis	Aurora brook trout	Truite aurore	T	4.1		X		
Salvelinus malma	Dolly Varden	Dolly Varden	R	4.1			X	X
Salvelinus namaycush	Lake trout	Touladi	R	4.2	X	X	X	X
Coregonus artedii	Lake herring	Cisco de lac	R	4.2		X	X	
Coregonus nigripinnis	Blackfin cisco	Cisco à nageoires noires	T	4.2		X	X	
Coregonus clupeaformis	Lake whitefish (opeongo)	Grand corégone	R	4.2	X	X	X	X
Coregonus canadensis	Atlantic whitefish	Corégone atlantique	R	4.2	X			
Prosopium cylindraceum	Round whitefish	Ménomini rond	R,T	4.2		X	X	X
Prosopium williamsoni	Mountain whitefish	Ménomini des montagnes	R	4.2			X	X
Stenodus leucichthys	Inconnu	Inconnu	R	4.2				X
Thymallus arcticus	Arctic grayling	Ombre arctique	R	4.2			X	X
FAMILY: OSMERIDAE								
Osmerus mordax	Rainbow smelt	Eperlan arc-en-ciel	R	4.1	X	X		X
Thaleichthys pacificus	Eulachon	Eulakane	R	4.2				X
FAMILY: HIODONTIDAE								
Hiodon alosoides	Goldeye	Laquaiche aux yeux d'or	R	4.3		X	X	X
Hiodon tergisus	Mooneye	Laquaiche argentée	R	4.2		X	X	
FAMILY: ESOCIDAE								
Esox americanus	Redfin pickerel	Brochet d'Amérique	R	4.3		X		
Esox vermiculatus	Grass pickerel	Brochet vermiculé	R	4.3		X		
Esox lucius	Northern pike	Grand brochet	R	4.3		X	X	X
Esox masquinongy	Muskellunge	Maskinongé	R	4.3		X		
Esox niger	Chain pickerel	Brochet maillé	R	4.3	X	X		
ORDER: CYPRINIFORMES FAMILY: CYPRINIDAE								
Clinostomus elongatus	Redside dace	Méné long	T	4.1		X		
Exoglossum maxillingua	Cutlips minnow	Bec-de-lièvre	T	4.3		X		
Rhinichthys cataractae (undescribed form)	Noody longnose dace	Naseux des rapides	T	4.2				X
Rhinichthys osculus	Speckled dace	Naseux moucheté	T	4.3				X

Freshwater fishes (cont'd)*

Scientific name	English	French	Status**	Life form	Atl.	Province Cont.	Prai.	B.C.
FAMILY: CATOSTOMIDAE								
Catostomus sp. (undescribed form)	Campbell sucker	Meunier de Campbell	T	4.3				X
Moxostoma carinatum	River redhorse	Suceur ballot	T	4.3		X		
Moxostoma hubbsi	Copper redhorse	Suceur cuivre	T	4.3		X		
FAMILY: ICTALURIDAE								
Ictalurus nebulosus	Brown bullhead	Barbotte brune	R	4.3	X	X	X	
Ictalurus punctatus	Channel catfish	Barbue de rivière	R	4.3		X	X	
ORDER: ANGUILLIFORMES **FAMILY: ANGUILLIDAE**								
Anguilla rostrata	American eel	Anguille d'Amérique	R	4.3	X	X		
ORDER: GADIFORMES **FAMILY: GADIDAE**								
Lota lota	Burbot	Lotte	R	4.3	X	X	X	X
Microgadus tomcod	Atlantic tomcod	Poulamon atlantique	R	4.3	X	X		
ORDER: GASTEROSTEIFORMES **FAMILY: GASTEROSTEIDAE**								
Gasterosteus sp.	Giant stickleback	Epinoche géante	T	4.3				X
Allolumpenus hypochromus	Y-prickleback		T	4.3				X
ORDER: PERCIFORMES **FAMILY: SERRANIDAE**								
Roccus americanus	White perch	Bar-perche	R	4.3	X	X		
Roccus chrysops	White bass	Bar blanc	R	4.3		X		
Roccus saxatilis	Striped bass	Bar rayé	R,T	4.3	X	X		
FAMILY: CENTRARCHIDAE								
Ambloplites rupestris	Rock bass	Crapet de roche	R	4.3		X	X	
Lepomis auritus	Redbreast sunfish	Crapet rouge	R	4.3	X			
Lepomis gibbosus	Pumpkinseed	Crapet-soleil	R	4.3		X		X
Lepomis macrochirus	Bluegill	Crapet arlequin	R	4.3		X		
Lepomis megalotis	Long-eared sunfish	Crapet à longues oreilles	T	4.3		X		
Micropterus dolomieui	Smallmouth bass	Achigan à petite bouche	R	4.3	X	X	X	X
Micropterus salmoides	Largemouth bass	Achigan à grande bouche	R	4.3		X		X
Pomoxis nigromaculatus	Black crappie	Marigane noire	R	4.3		X		X
FAMILY: PERCIDAE								
Perca flavescens	Yellow perch	Perchaude	R	4.3	X	X	X	X
Stizostedion canadense	Sauger	Doré noir	R	4.3		X	X	
Stizostedion vitreum	Walleye	Doré	R	4.3		X	X	X
Percina copelandi	Channel darter	Dard gris	T	4.3				
FAMILY: SCIAENIDAE								
Aplodinotus grunniens	Freshwater drum	Malachigan	R	4.3		X	X	
FAMILY: COTTIDAE								
Cottus confusus	Shorthead sculpin	Chabot à tête courte	T	4.1				X

* The names of fishes adopt the systems used by Scott and Crossman (1974).

** Status
R : Recreational and commercial species; T : rare, threatened or endangered species; P : potential pest species

Amphibians and reptiles*

Scientific name	English	French	Status**	Life form	Province			
					Atl.	Cont.	Prai.	B.C.
CLASS: AMPHIBIA ORDER: CAUDATA FAMILY: AMBYSTOMATIDAE								
Dicamptodon ensatus	Pacific giant Salamander	***	T	3.5				X
Ambystoma jeffersonianum	Jefferson's Salamander	Salamandre de Jefferson	T	3.5		X		
Ambystoma platineum	Silvery Salamander			3.5		X		
FAMILY: PLETHODONTIDAE								
Desmognathus fuscus	Dusky Salamander	Salamandre sombre	T	3.5	X			
Hemidactylium scutatum	Four-toed Salamander		T	3.5	X	X		
Gyrinophilus porphyriticus porphyriticus	Northern Spring Salamander		T	3.5		X		
ORDER: ANURA FAMILY: LEIOPELMATIDAE								
Ascaphus truei truei	Olympic Tailed Frog		T	3.5				X
FAMILY: HYLIDAE								
Hyla versicolor versicolor	Eastern Gray Treefrog		T	3.5	X			
FAMILY: RANIDAE								
Rana septentrionalis	Mink Frog	Grenouille du nord	T	3.5	X			
Rana pipiens	Leopard Frog	Grenouille léopard	T	3.5	X			
Rana palustris	Pickerel Frog	Grenouille des marais	T	3.5		X		
CLASS: REPTILIA ORDER: TESTUDINES FAMILY: EMYDIDAE								
Clemmys guttata	Spotted Turtle	Tortue ponctuée	T	3.2		X		
Clemmys marmorata marmorata	Northwestern Pond Turtle		T	3.2				X
Clemmys insculpta	Wood Turtle	Tortue des bois	T	3.2		X		
Emys blandingi	Blanding's Turtle	Tortue de Blanding	T	3.2	X	X		
Terrapene carolina	Eastern Box Turtle		T	2.6		X		
FAMILY: TRIONYCHIDAE								
Trionyx ferox spinifera	Eastern Spiny Soft-shelled Turtle	Tortue à carapace molle	T	3.2		X		
ORDER: SQUAMATA SUBORDER: LACERTILIA FAMILY: IGUANIDAE								
Phrynosoma douglassi brevirostre	Eastern Short-horned Lizard		T	2.4			X	
SUBORDER: SERPENTES FAMILY: BOIDAE								
Charina bottae bottae	Pacific Rubber Boa		T	1.2				X
Charina bottae utahensis	Rocky Mountain Rubber Boa		T	1.2				X
FAMILY: COLUBRIDAE								
Natrix sipedon sipedon	Northern Water Snake	Couleuvre d'eau	T	3.2		X		
Thamnophis sauritus sauritus	Eastern Ribbon Snake		T	3.2	X			
Heterodon nasicus nasicus	Plains Hognose Snake		T	2.4			X	
Diadophis punctatus edwardsi	Northern Ring-necked Snake	Couleuvre à collier	T	2.4	X	X		
Coluber constrictor mormon	Western Yellow-bellied Racer		T	2.4			X	X
Opheodrys vernalis vernalis	Eastern Smooth Green Snake	Couleuvre verte	T	2.4		X		
Elaphe vulpina gloydi	Eastern Fox Snake		T	2.4		X		
Elaphe obsoleta obsoleta	Black Rat Snake		T	2.6		X		
Pituophis catenifer catenifer	Pacific Gopher Snake							X
Lampropeltis doliata triangulum	Eastern Milk Snake	Couleuvre tachetée	T	2.6		X		
Contia tenuis	Sharp-tailed Snake							X
FAMILY: CROTALIDAE								
Sistrurus catenatus catenatus	Eastern Massasauga		T	3.2		X		
Crotalus viridis viridis	Prairie Rattlesnake		T	2.4			X	

* The names of amphibians and reptiles adopt the systems used by Logier and Toner (1961) and Melançon (1961).

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*** French common names are from Melançon (1961) and only available for species encountered in the province of Québec (Drolet, pers. comm.).

POOR

QUALITY

ORIGINAL